

Fayetteville Works Conceptual Site Model (CSM) Update

January 31 2019

Overview

Today's Objectives:

Share Site Conceptual Site Model, including refinements from last update (October 2018)

CSM

- Site setting (Geology, River, Pathways)
- PFAS Compounds
- Site PFAS Data (Residential, Soil, Groundwater, Outfall 002)
- River PFAS Data (River)
- River Mass Flux Model



Data Considered / Investigations Conducted

Sampling Program Investigation Name	Date	Groundwater	Residential Groundwater	Cape Fear River	Tributaries	Outfall 002	Soil / Leachate	Air	Wipe Samples	Rain Water
RCRA Program Investigations	Pre-2017	✓		✓	✓		✓			
Supplemental Groundwater Sampling	Aug-17	✓				✓				
Supplemental Soil and Surface Water Sampling	Aug-17				✓		✓			
Cape Fear River - Local 1	Sep-17			✓	✓	✓				
Additional Investigation	Nov-17	✓				✓	✓			
Stack Testing	Jan-18							✓		
Stormwater Sampling	Jan-18	✓			✓	✓				
Former Outfall Sampling	Feb-18				✓					
VE-South Investigation	Feb-18						✓		✓	
Cape Fear River - Local 2	May-18			✓	✓	✓				
Cape Fear River – Regional	Jun-18			✓	✓	✓				
Terracotta Pipe Investigation	Jul-18	✓					✓			
South East Perched Zone Investigation	Fall 2018	✓								
Blast Zone Investigation	Fall 2018	✓								
Residential Program	On-going		✓							
Rain Water Program	On-going									✓

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Actions Taken and Underway

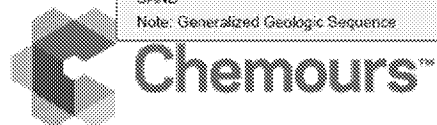
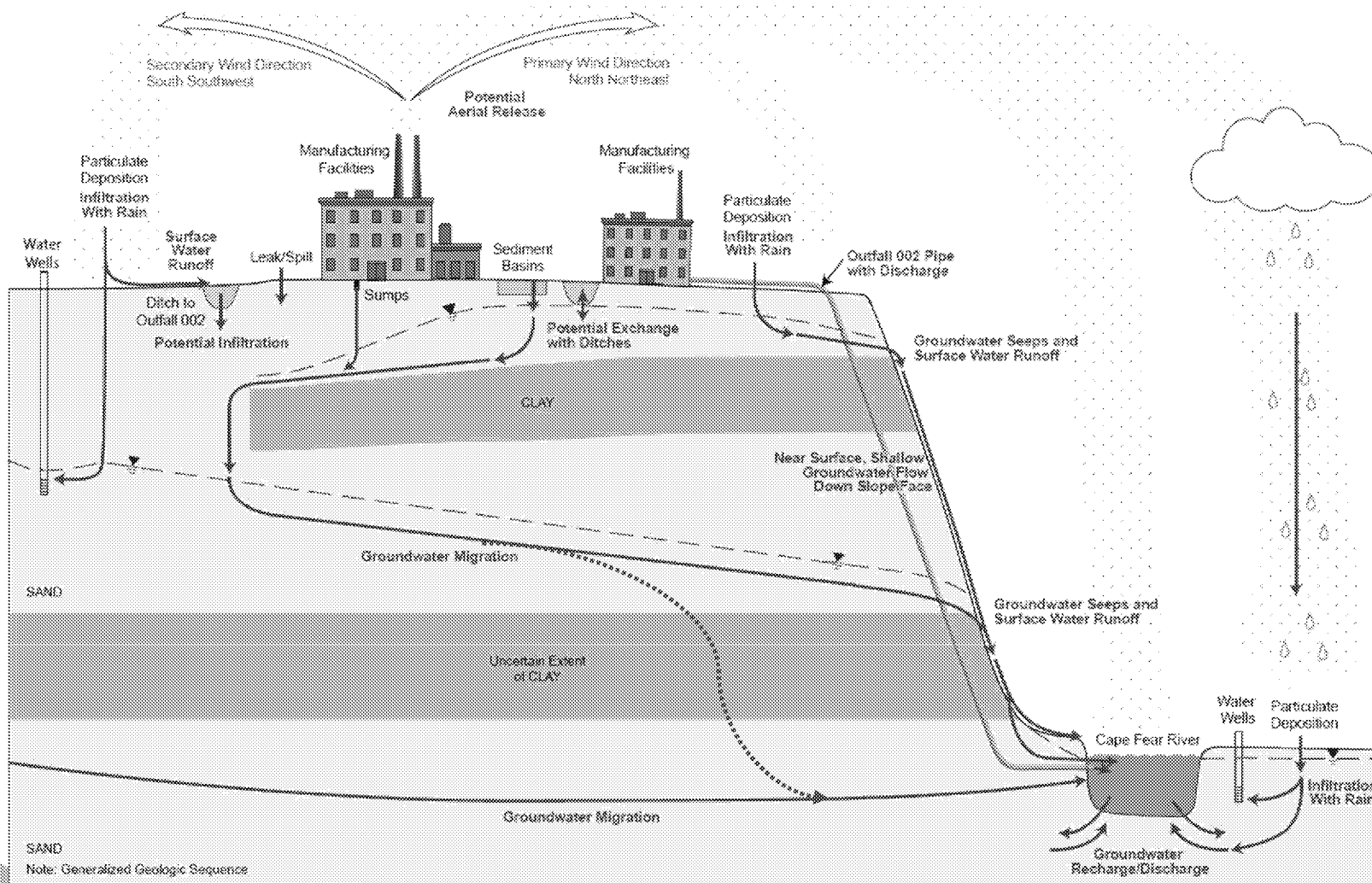
Abatement Action	Implemented	Underway	In-Design
Diversion of Process Waste Water	✓		
Targeted Site Groundwater Extraction	✓	✓	
Line Cooling Water Channel	✓		
Line Sedimentation Ponds	✓		
Treatment of Old Outfall Water			✓
Residential Treatment Systems	✓	✓	
Process Air and Water Emissions Abatement	✓	✓	✓
Consent Order Paragraph 12 & 16 Actions			✓

Chemours is taking multiple, rapid actions to:

- Reduce process emissions of PFAS to the environment including the River
- Reduce flux of PFAS to the Cape Fear River

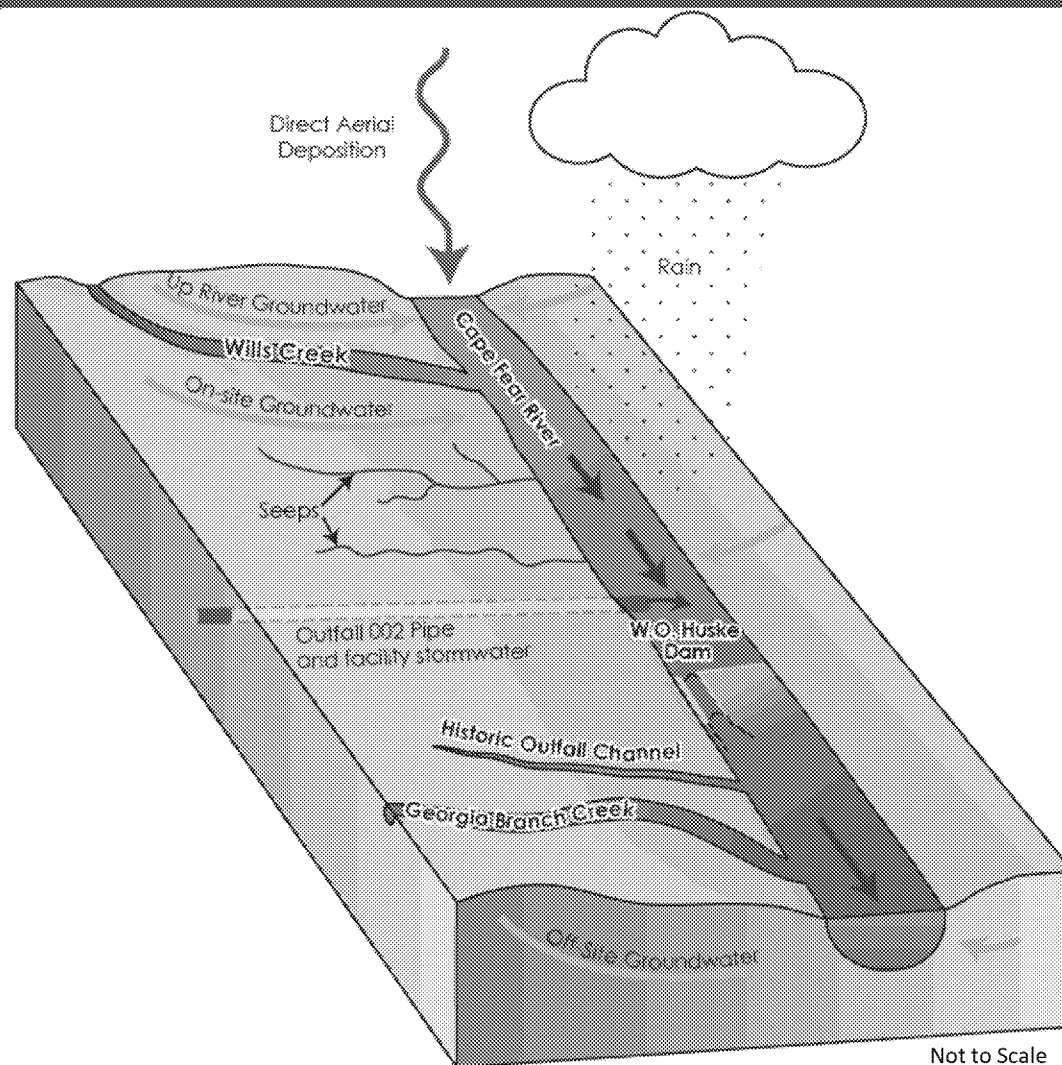


Conceptual Site Model Diagram



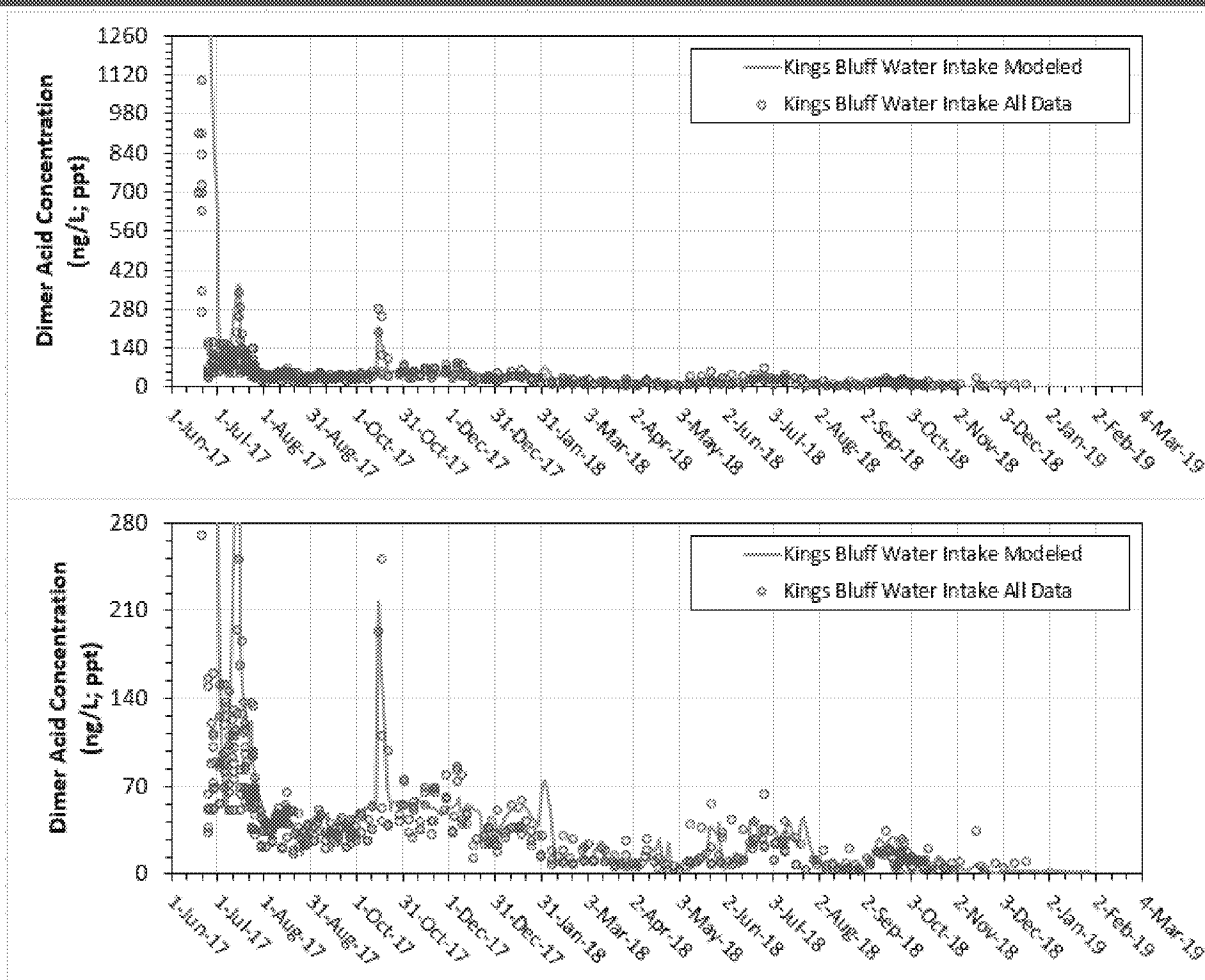
Not to Scale. Vertical exaggeration to show lithology.

River Mass Flux Inputs Diagram



Mass Flux Model Estimated vs. Observed River Concentrations

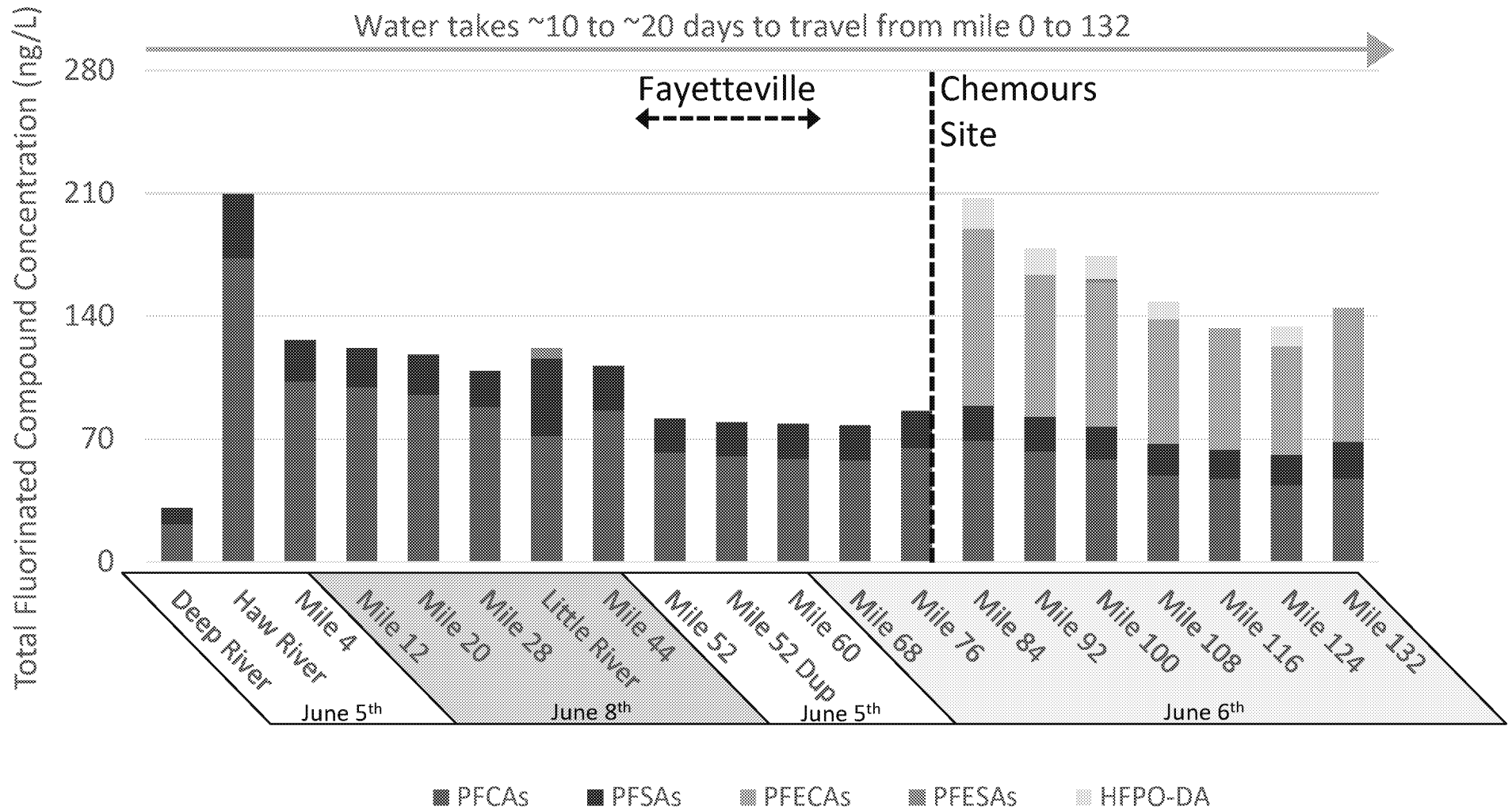
Zoomed In
y axis



- Kings Bluff Intake Canal.
- Data sources: Primarily CFPUA, Brunswick County and NCDEQ



Regional River Program PFAS Data

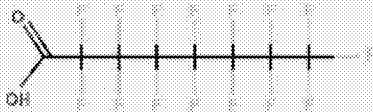
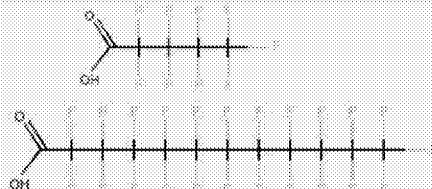

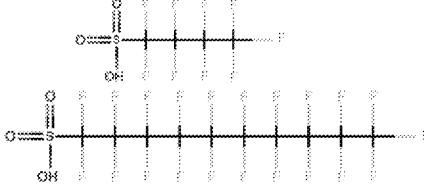
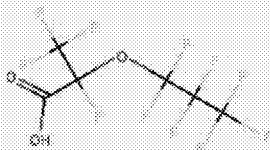
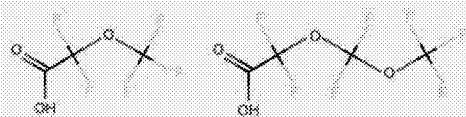
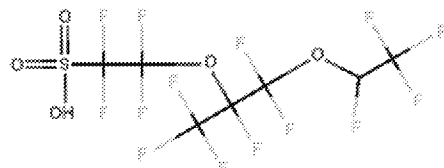


ng/L – nanograms per liter, equivalent to ppt (part per trillion) * Dup – Duplicate sample



PFAS Compounds Overview

PFAS Types

Class	Product	Byproducts & Associated Compounds
Perfluoroalkyl carboxylic acids (PFCAs) <u>EPA 537 Mod</u>	PFOA 	Other longer and shorter PFCAs 
Perfluoroalkyl sulfonic acids (PFSA) <u>EPA 537 Mod</u>	PFOS 	Other longer and shorter PFSA 
Perfluoroalkyl ether carboxylic acids (PFECAs) <u>EPA 8321 Mod & Table 3 SOP</u>	HFPO-DA (i.e. GenX) <u>EPA 8321 Mod</u> 	Other ethers, e.g. PFMOAA <u>Table 3 SOP</u> 
Perfluoroalkyl ether sulfonic acids (PFESAs) <u>Table 3 SOP</u>	Nafion - Polymerized Monomers -	Nafion Monomers etc., (i.e. byproducts) 

PFAS Analytical Methods

Analytical Method	PFAS Quantified
EPA 537 Mod	PFCAs, PFSAAs, others (e.g. sulfanoamides, telomers, etc.,)
EPA 8321 Mod	HFPO-DA (i.e. GenX) <i>[can do with methods 537 and Table 3]</i>
Table 3 SOP	PFECAs & PFESAs

Analytical capabilities continue to develop;
more compounds are being added

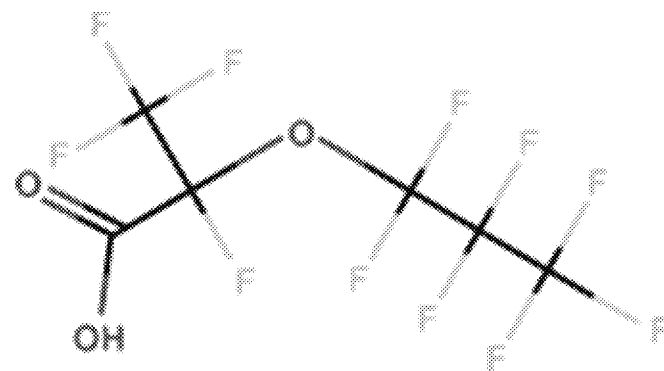
Acronyms

- PFAS – per- and polyfluoroalkyl substances
- PFCAs – perfluorocarboxylic acids
- PFSAAs – perfluorosulfonic acids
- HFPO-DA – Hexafluoropropylene oxide dimer acid (i.e. C3-HFPO-DA GenX)
- PFECAs – Perfluoroethersulfonic acids
- PFESAs – Perfluoroethersulfonic acids
- PFMOAA – Perfluoro-1-methoxyacetic acid
- PFOA – perfluorooctanecarboxylic acid
- PFOS – perfluorooctanesulfonic acid



HFPO-DA Characteristics & Anticipated Fate Data from DuPont studies

- Common shortened names: HFPO-DA, C3DA, HFPO-DA, GenX, FRD-903
- Other forms: C3 HFPO-DA ammonium salt
Negative charge paired with a positively charged ammonium ion, NH_4^+
- Acid dissociation (pKa): 2.45.
Will be negatively charged in most natural waters.
- Biodegradation: not anticipated
- Solubility in water: 100% (infinite)
- Octanol-water partition coefficient, K_{ow} : 2
Organic carbon-water partition coefficient, K_{oc} : 12 to 12.6
Mobile in aquifer. Some sorption to activated carbon.
Activated carbon is a stronger sorbent than the aquifer.
Empirical measurements by DuPont Haskell Laboratory
- Density for a solution of 86% HFPO-DA and 14% water: 1.7 g/mL at 20°C
- Vapor pressure of 2.3 mm-Hg at 20°C



	Air	Soil	Groundwater	Surface Water
Anticipated Fate	Possibly transported adhered to particles	Can leach to groundwater with precipitation events	Flows with groundwater; limited retardation	Concentrations reduced primarily by dilution



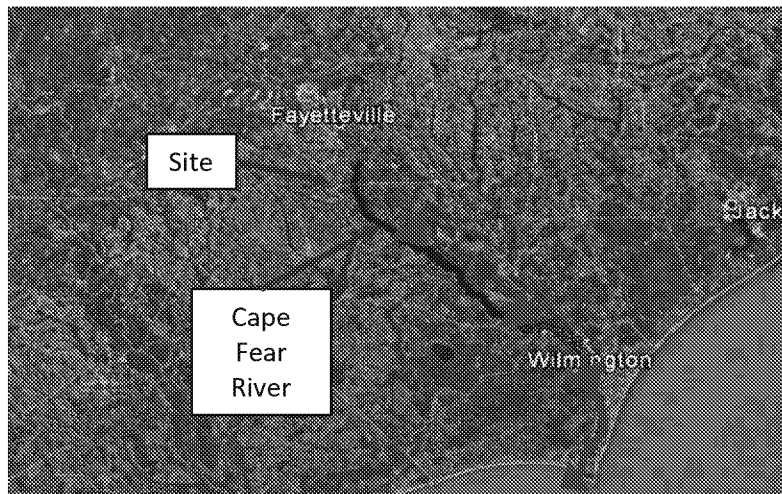
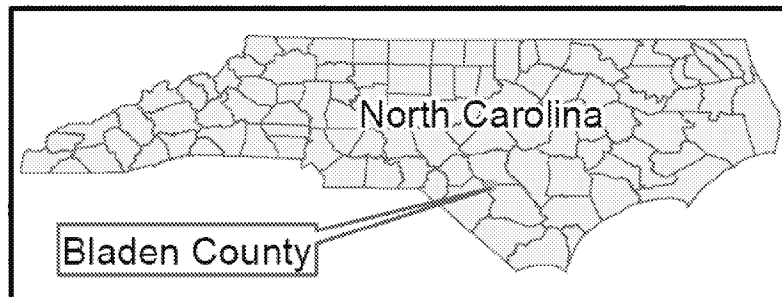
Site Setting

Site Location

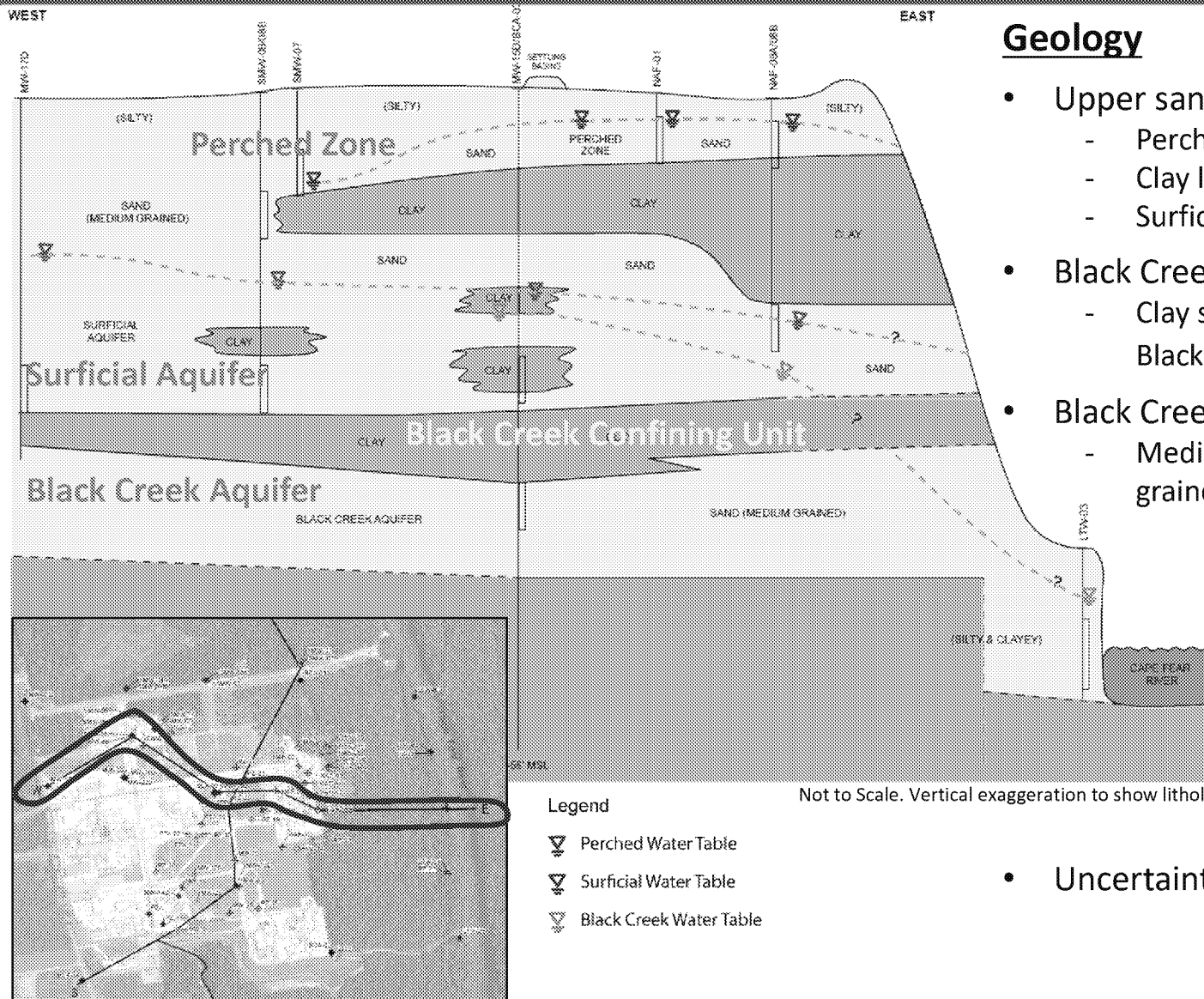
Fayetteville Works: 2,200-acre property northwestern Bladen County, NC

Location: 22828 NC-87, Fayetteville, NC 28306, USA; Bladen County

Topography: Mostly flat. River to the East down a ~90 feet bluff/hill



Site Geology & Hydrogeology

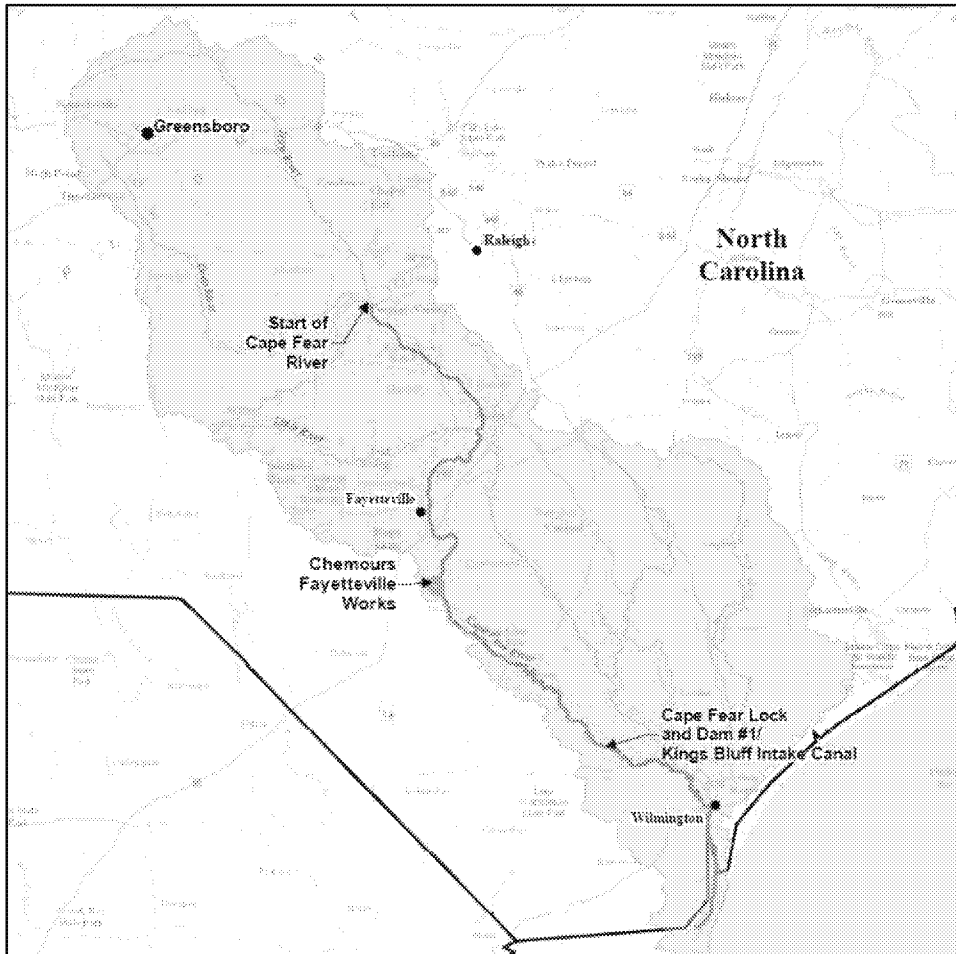


Geology

- Upper sand unit is divided into:
 - Perched Zone - medium sand
 - Clay lens – below Site
 - Surficial Aquifer – medium sand
- Black Creek Confining Unit
 - Clay separating surficial Aquifer from Black Creek Aquifer
- Black Creek Aquifer
 - Medium sands. Becomes finer grained closer to the river.

Uncertainties/Data Gaps

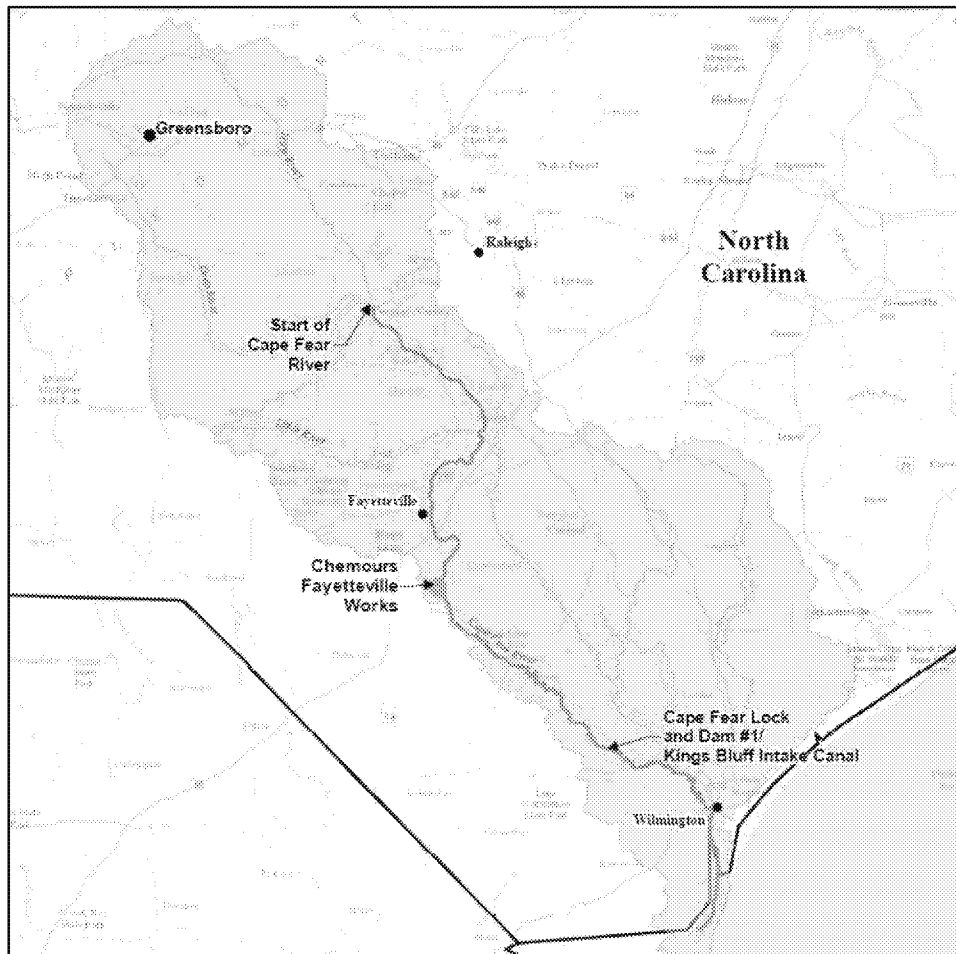
Cape Fear River Watershed



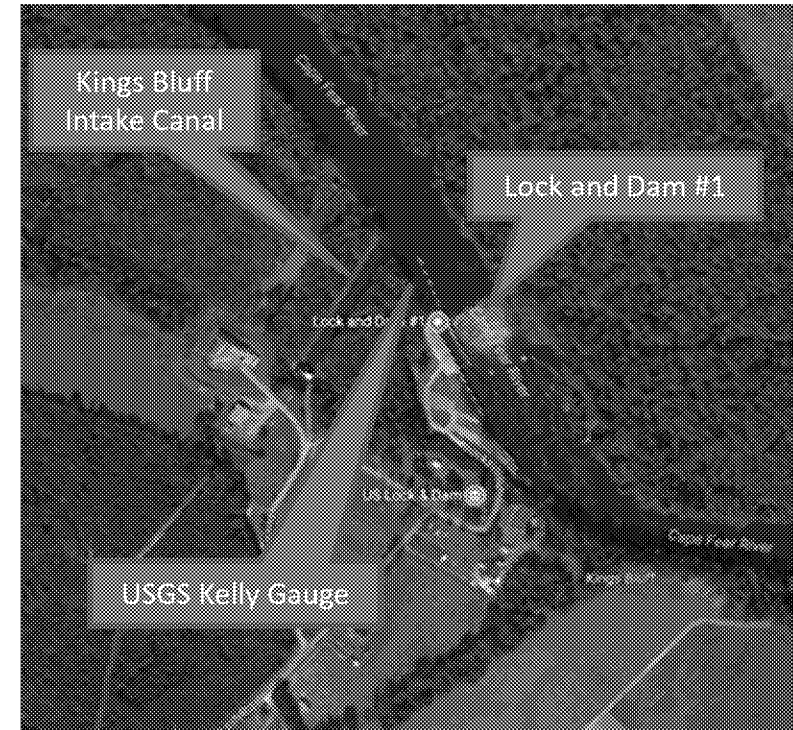
- Entire catchment 9,164 square miles.
 - River Drains 4,852 square miles at Site.
 - River Drains 5,255 square miles at Kings Bluff Intake.
 - An 8% increase in drainage area between Site and Kings Bluff Intake.
- River Mile Distances from River Start:
 - River Mile 76.5: WO Huske USGS Gauge.
 - River Mile 83: Bladen Bluffs.
 - River Mile 132: Kelly USGS Gauge.
 - River Mile 132: Kings Bluff.
 - River Mile 167: Site to Wilmington.
- Kings Bluff Intake – Water Source for:
 - CFPUA (i.e. Wilmington, NC)
 - Pender County
 - Brunswick County



Public Utilities' Intake Location



- Kings Bluff Intake – Water Source for:
 - CFPUA (i.e. Wilmington, NC)
 - Pender County
 - Brunswick County



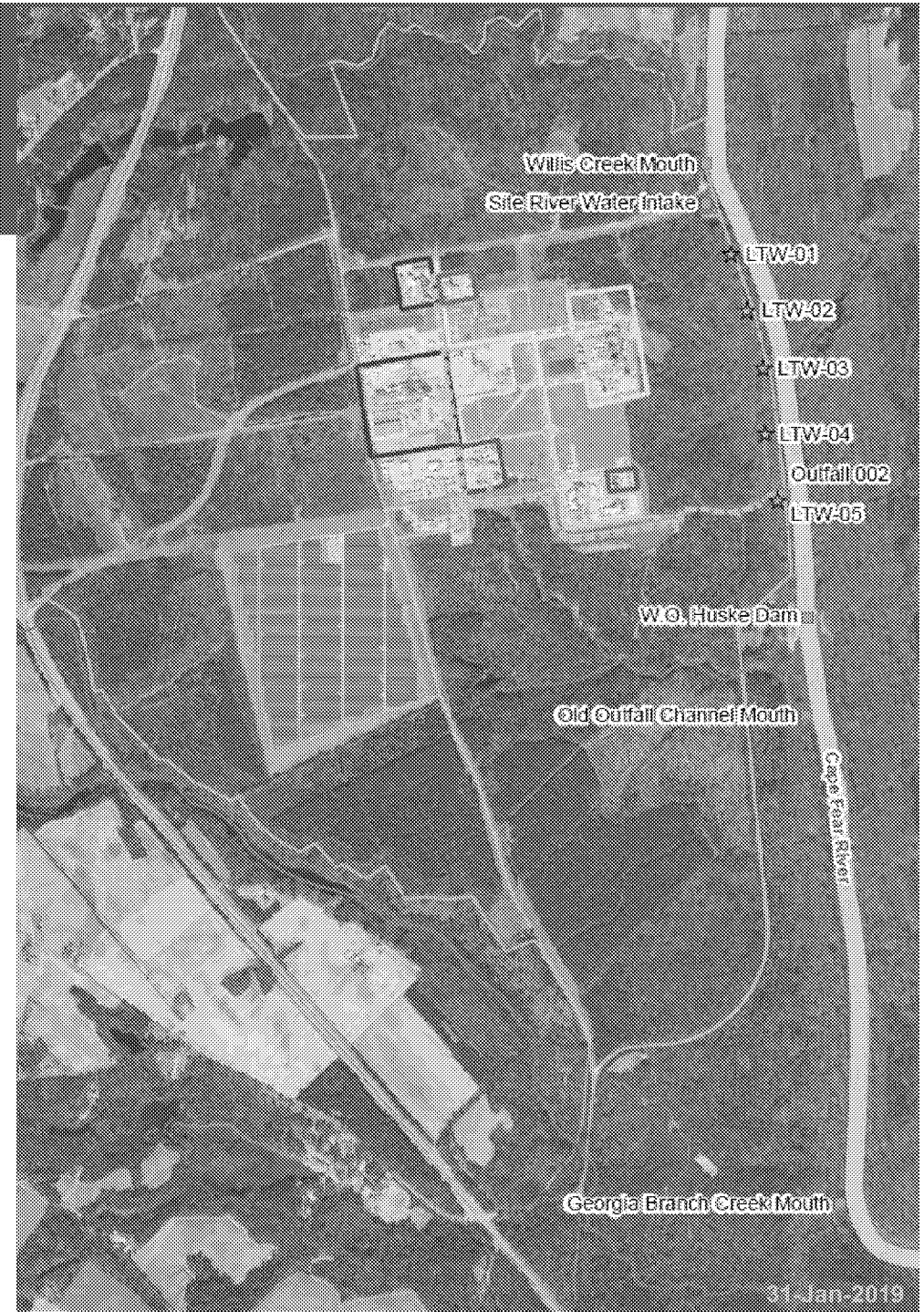
<http://www.lcfwasa.org/facilities-and-customers>



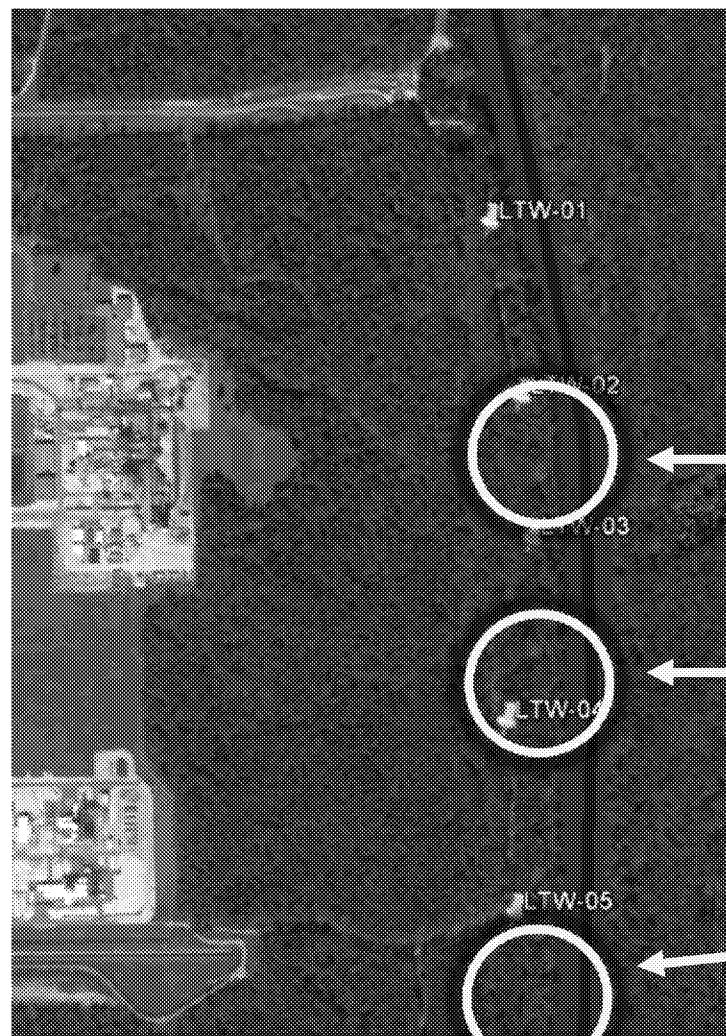
Site at River

- River to East of Site
- River at Bottom of Bluff
- Key Features
 - Willis Creek
 - Site River Water Intake
 - LTW Wells
 - Outfall 002
 - Old Outfall Channel
 - Georgia Branch Creek
 - Seeps at Site

Legend		Areas at Site	
★	LTW - Long Term Wells	□	Chemours Monomers IXM
■	Site Features	□	Chemours PPA
▨	Cape Fear River	□	Dupont / Dow Leased
—	Nearby Tributaries	□	Former Teflon Production
▤ ▥ ▦	Drainage Network	□	Kuraray America Leased
⋯	Site Boundary	□	Wastewater Treatment Plant



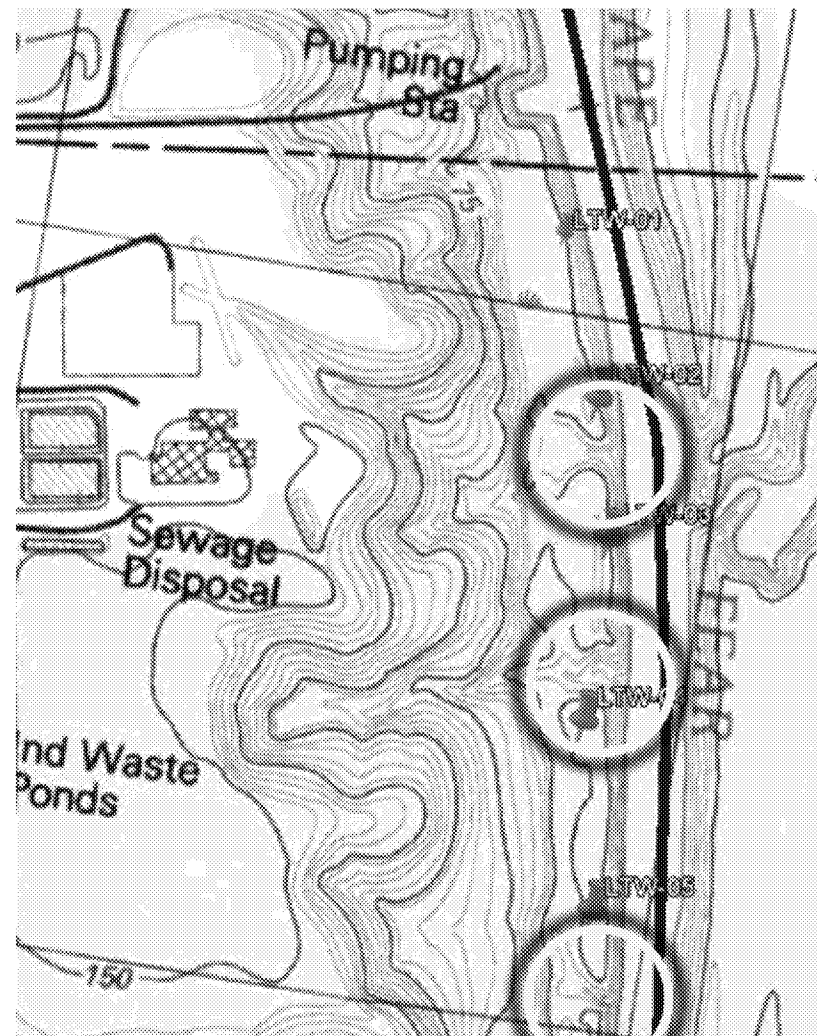
Seeps at River



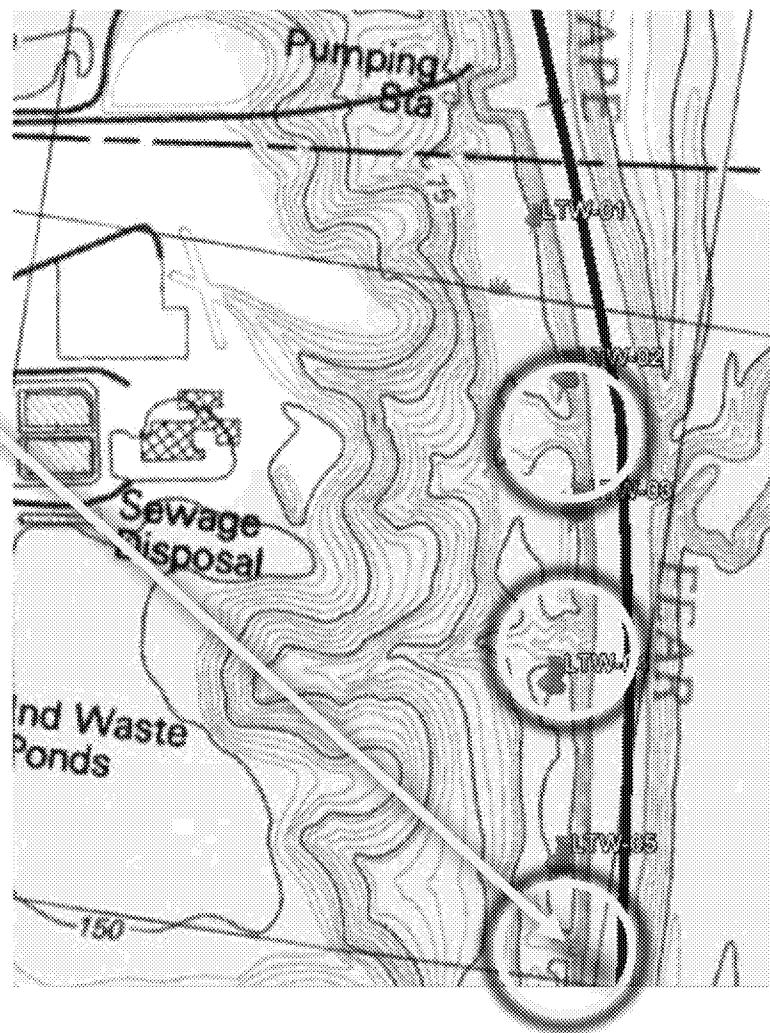
North
Seep

Center
Seep

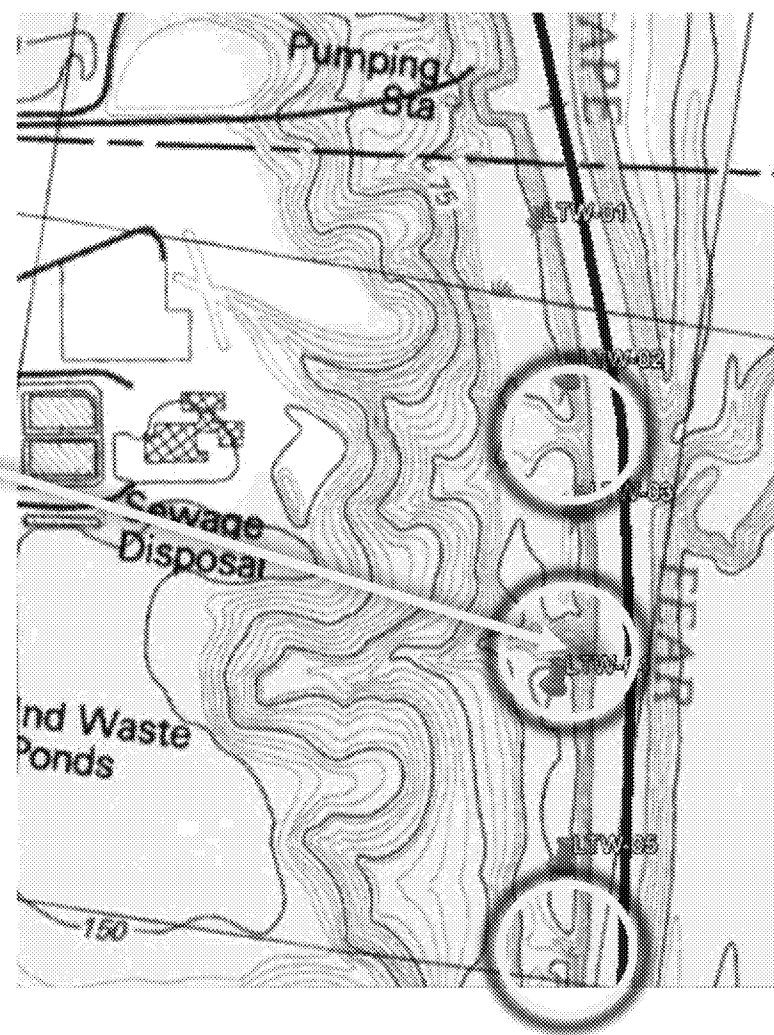
South
Seep



South Seep Near River



Center Seep Near River

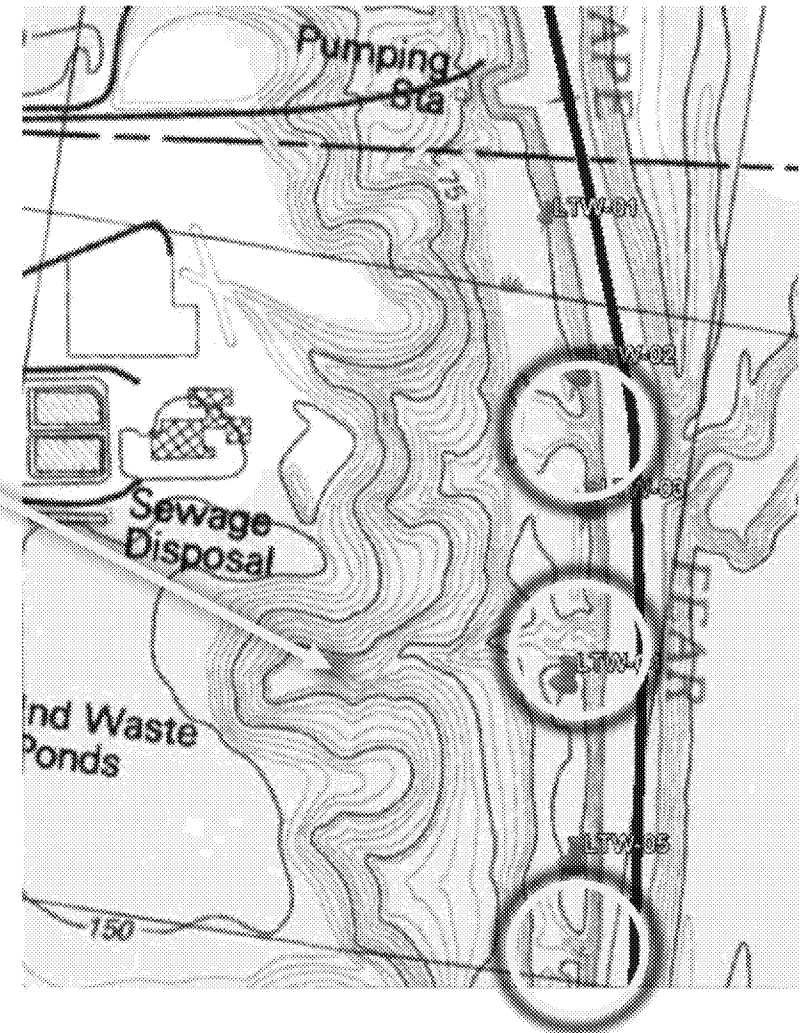


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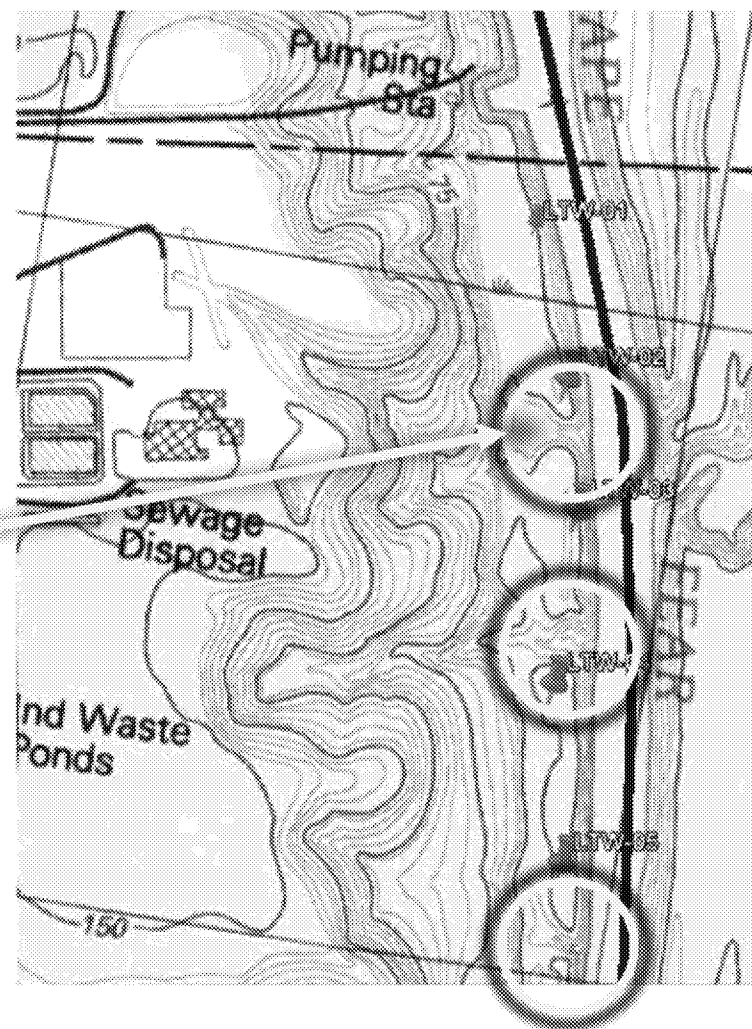
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Perched Zone Seeping Water



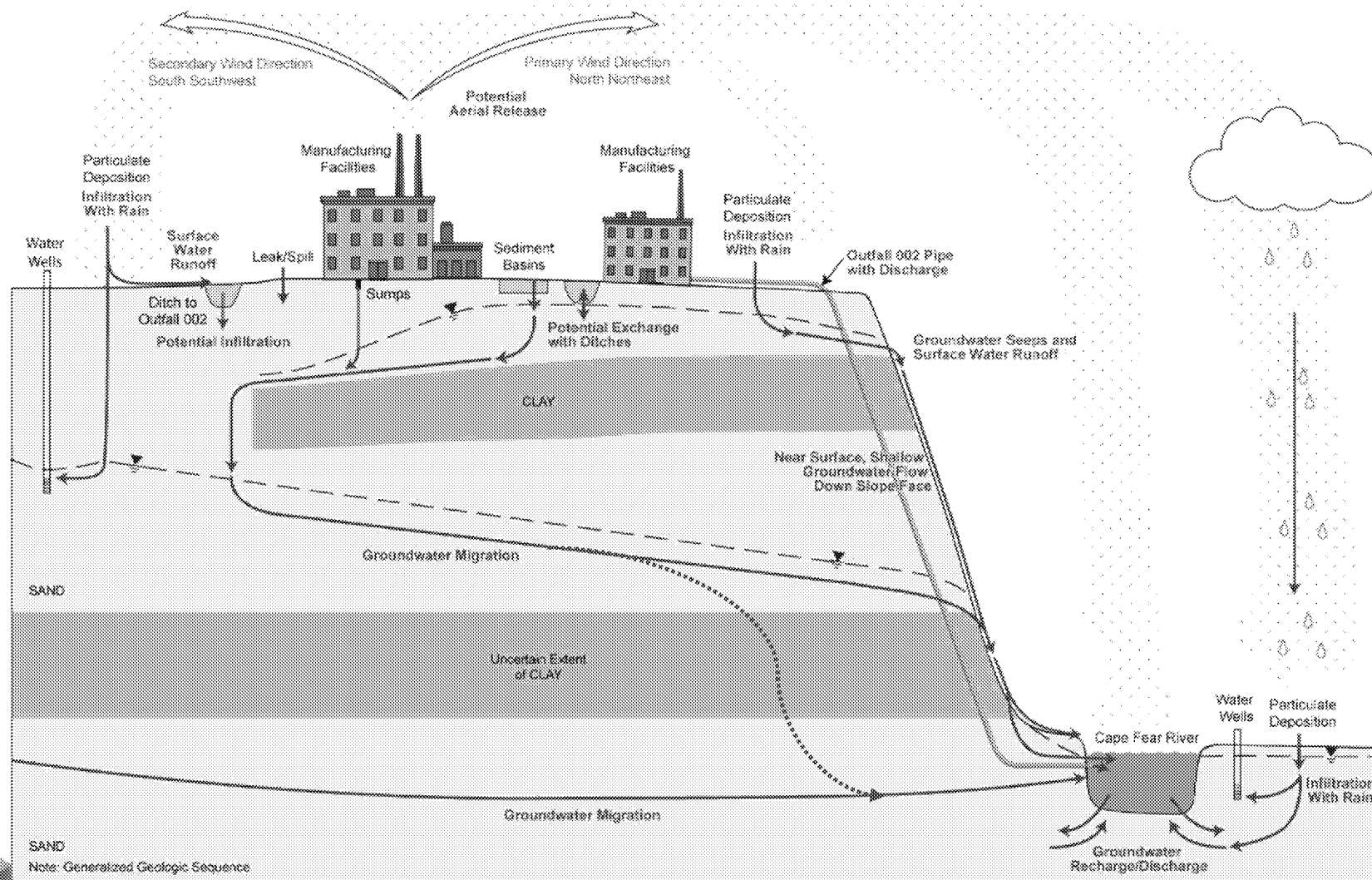
North Seep at River



Seeps Summary

- Identified three locations where flow from combined seeps enters the Cape Fear River from Site property
- Likely includes seepage contributions from:
 - Perched Zone
 - Potentially Surficial Aquifer
 - Potentially Black Creek Aquifer
- Seep volumetric flow and concentrations will be investigated

Conceptual Site Model Diagram



Not to Scale. Vertical exaggeration to show lithology.

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HFPO-DA:

Air, Soil, Groundwater, Outfall 002

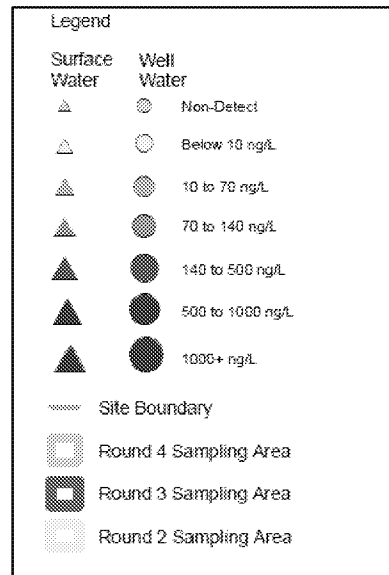
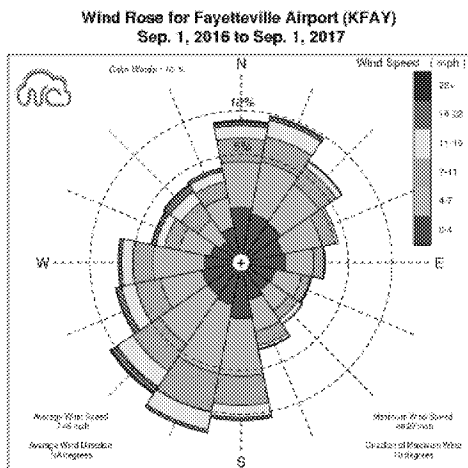
Historical PFAS Release Points

Historical PFAS Release Points	Resultant PFAS Detections
Air Emissions	Residential Well Groundwater Site Groundwater Outfall 002 Site and Surrounding Soils
Wastewater to Outfall 002 Prior June 21, 2017	Cape Fear River Black Creek Aquifer by River
Terra Cotta Pipe	Perched and Surficial Groundwater Old Outfall 002 via Groundwater
October 2017 Scrubber Upset	Surficial Soils Perched Groundwater Outfall 002



Air to Soil Residential Well Sampling Results

- Residential Well Data available through December-2018. Includes both Chemours and NCDEQ results.
- Wind rose shows wind directions.
- Aerial deposition occurs in all directions.
- Deposition aligned with primary and secondary wind directions.



Wind Rose Source: <http://www.nc-climate.ncsu.edu/windrose?state=NC&station=KFAY>

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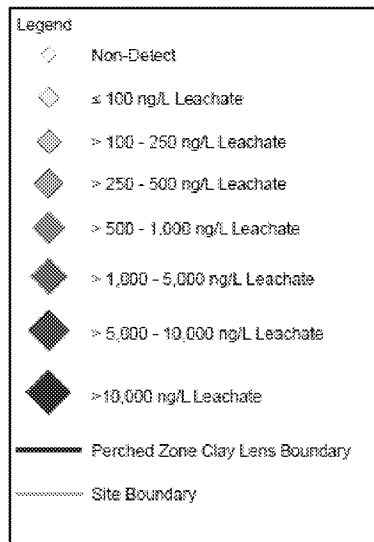
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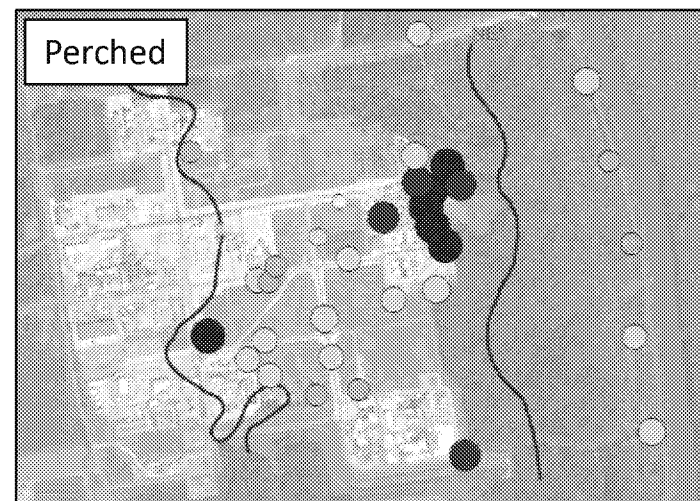
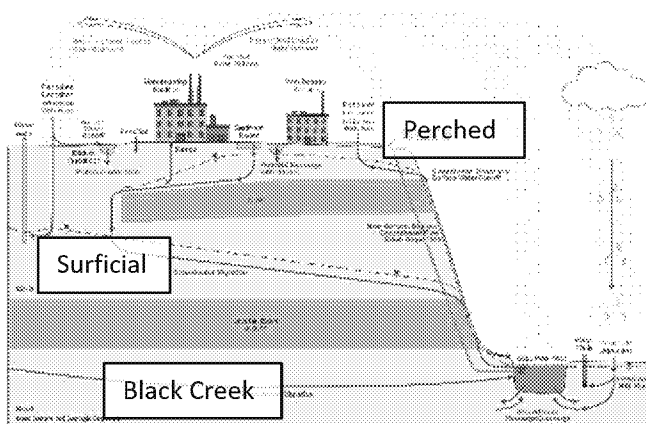
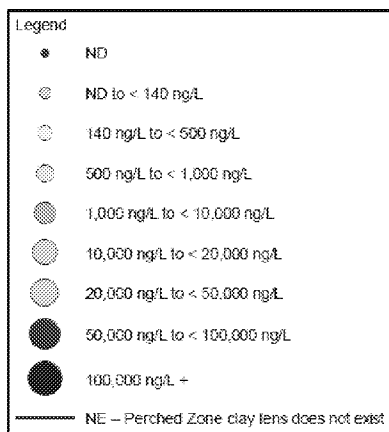
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Soil Leachate HFPO-DA Data 28 November to 1 December 2017

- Synthetic precipitation leaching procedure (SPLP) performed for top 6 inches of Site soil samples.
- Leachate extract (2-L water per 100-g soil) analyzed for HFPO-DA.
- Spatial distribution is similar to groundwater, highest concentration near Vinyl Ethers South (VES).

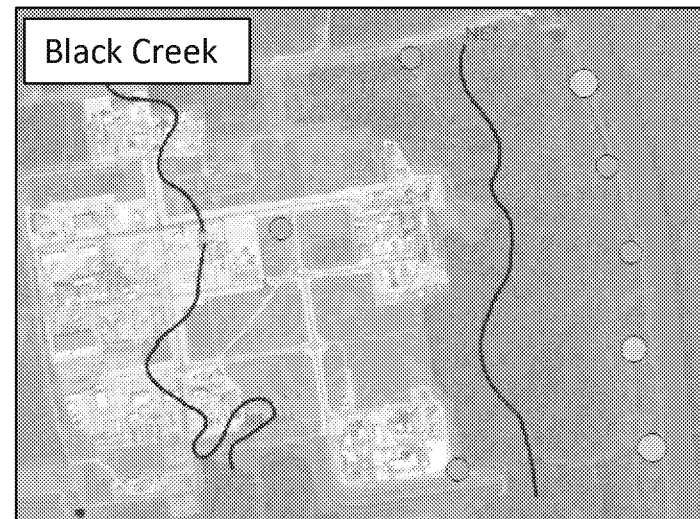
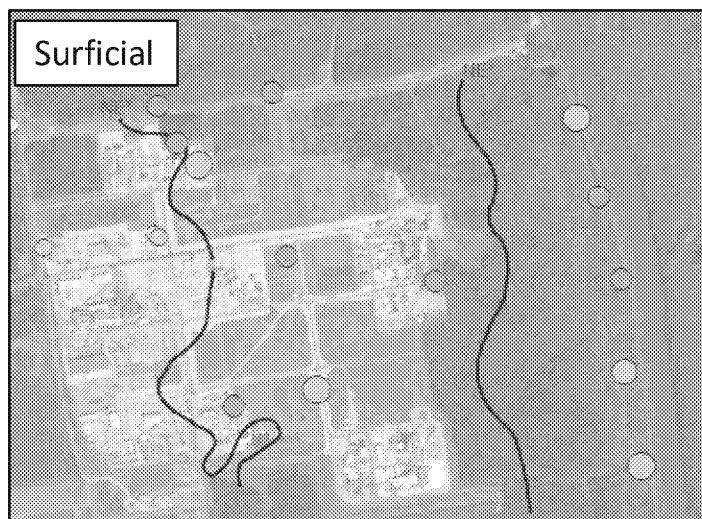


Groundwater HFPO-DA Data November & December 2017

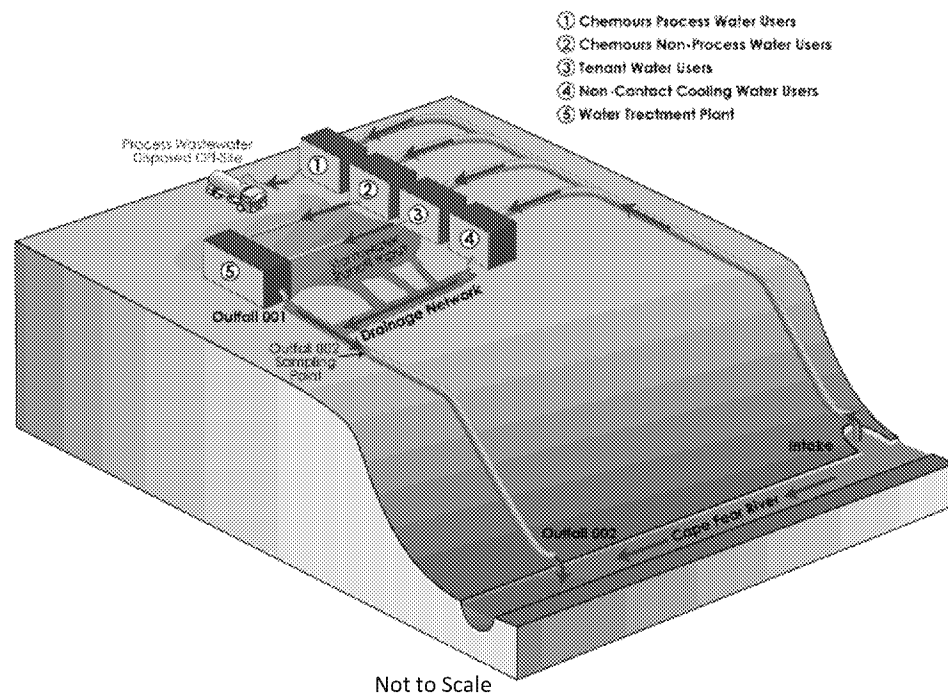
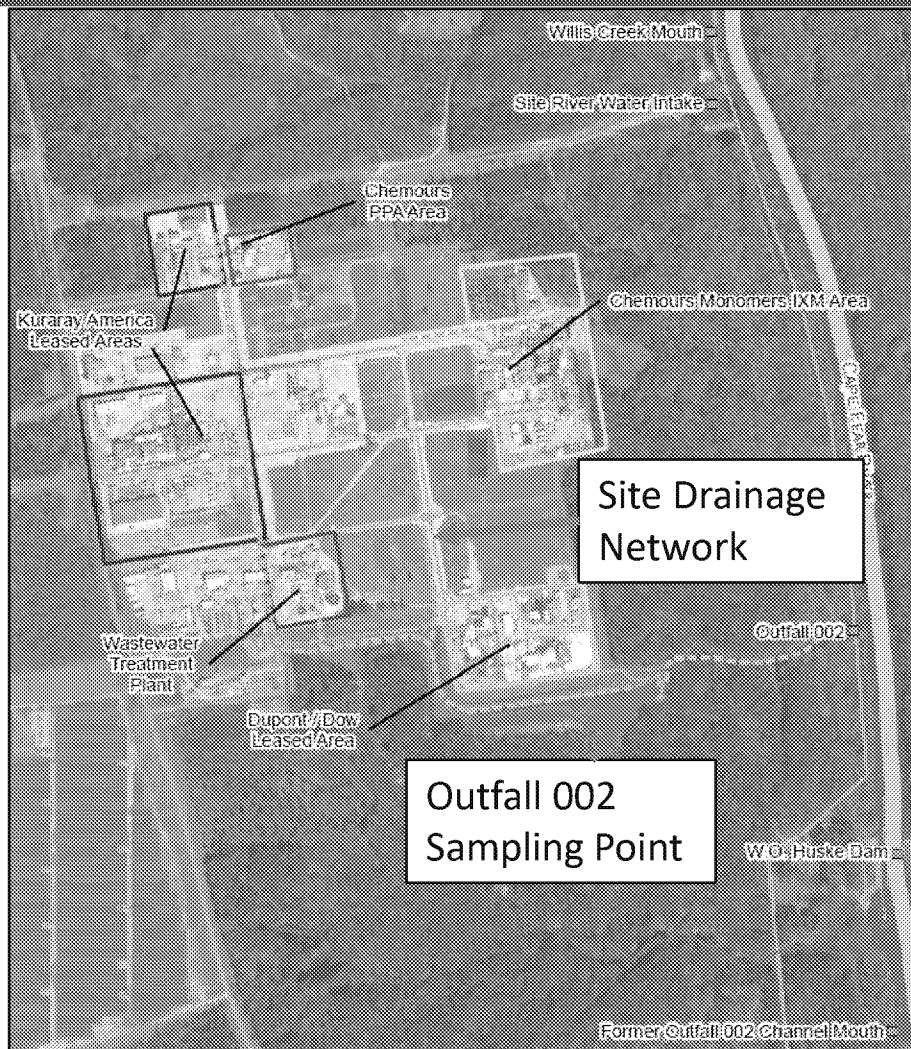


Note

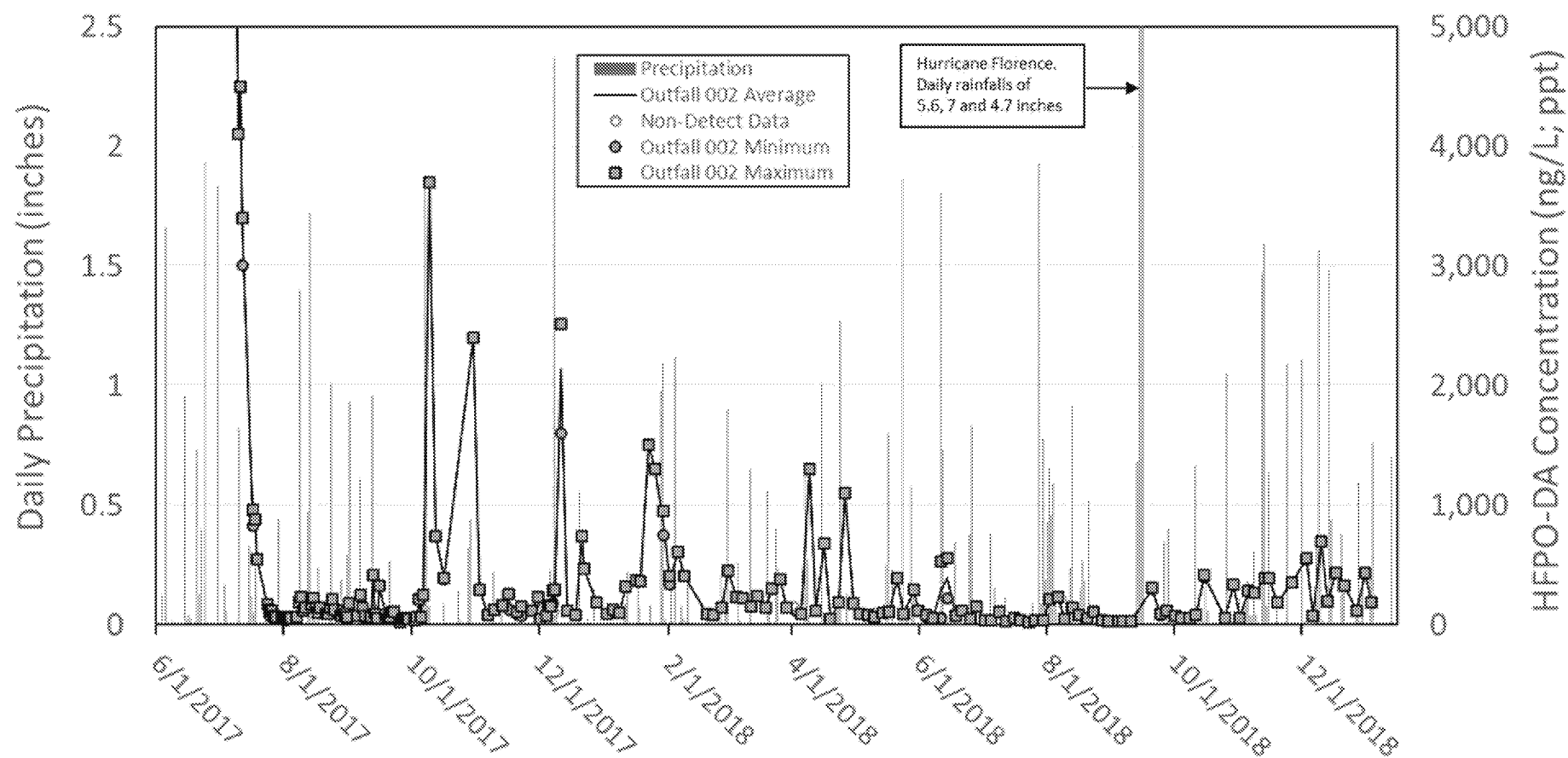
The 5 Long Term Wells (LTW) at the river are repeated in each figure.



Site Drainage Network and Outfall 002 and Present Water Use at Site



Outfall 002 Concentrations



Outfall 002 captures: non-contact cooling water, treated Kuraray and DuPont process wastewater, treated sanitary wastewater and stormwater from the facility



HFPO Data: *Surface Water*

PFAS in Cape Fear River PFOA, PFOS, etc.,

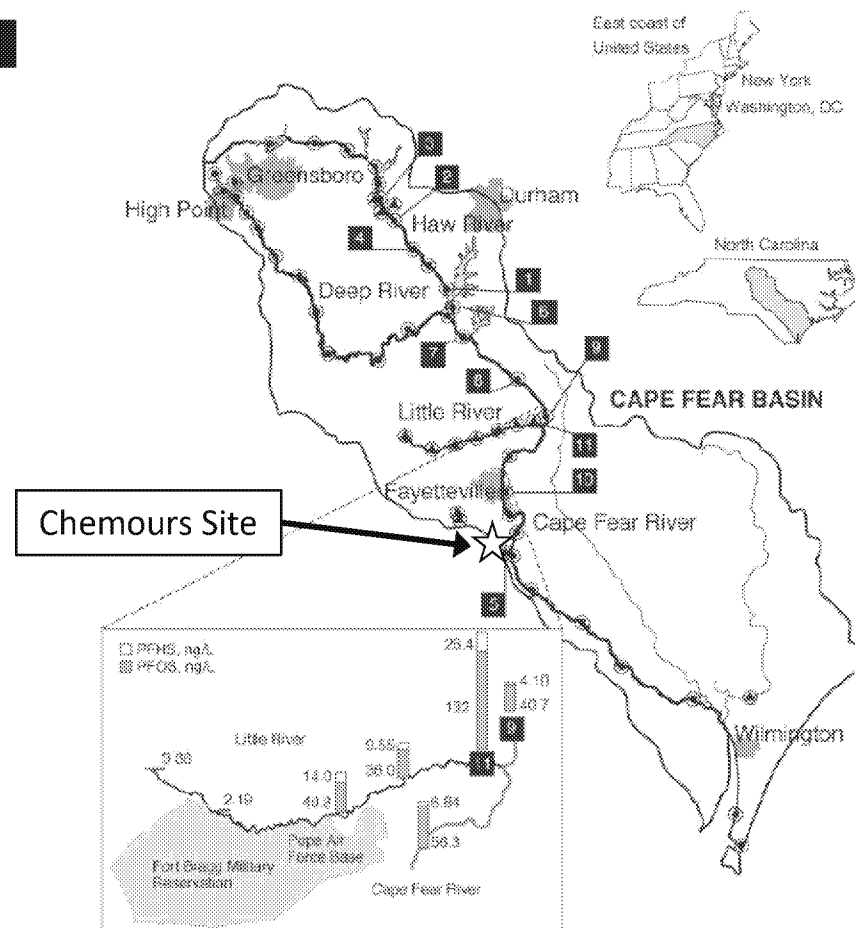
Environ. Sci. Technol. **2007**, *41*, 5271–5276

Perfluorinated Compounds in the Cape Fear Drainage Basin in North Carolina

SHOJI NAKAYAMA, MARK J. STRYNAR,
LAURENCE HELFANT, PETER EGEGHY,
XIBIAO YE, AND
ANDREW B. LINDSTROM*

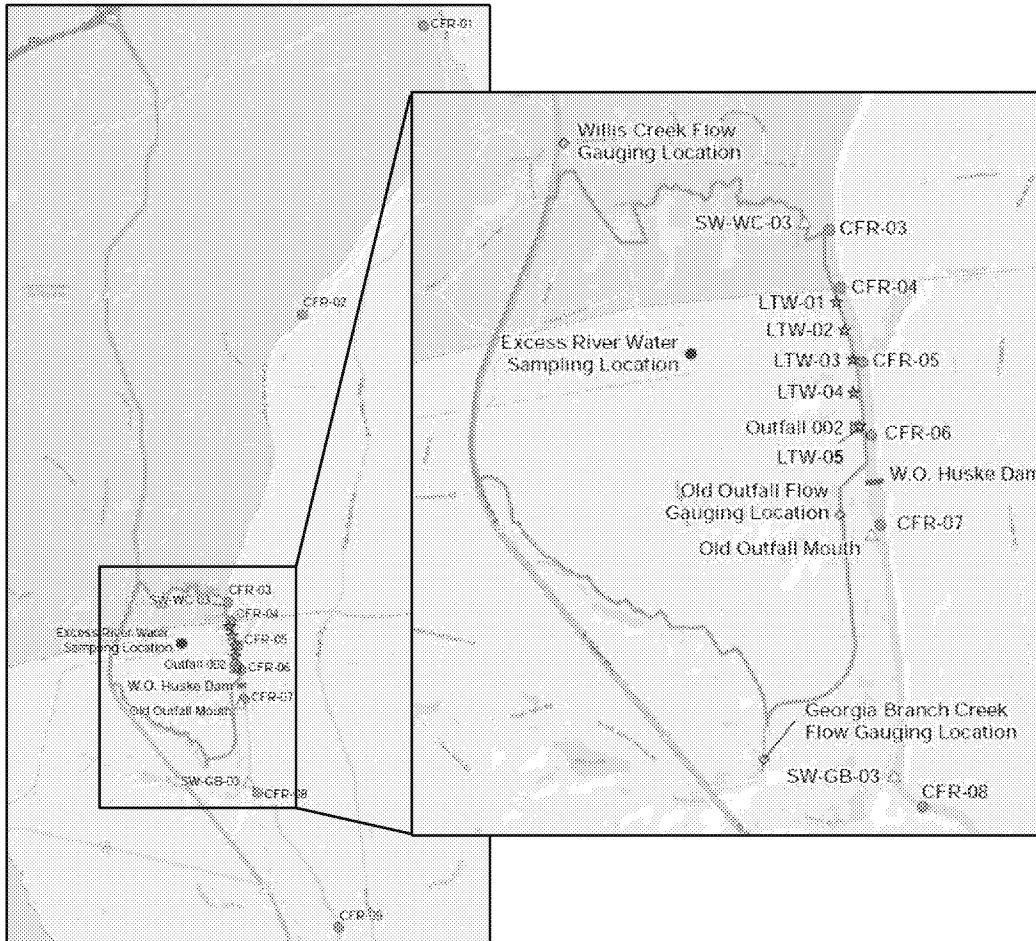
*National Exposure Research Laboratory, U.S. Environmental
Protection Agency, Research Triangle Park,
North Carolina 27711*

- PFAS are present throughout
Cape Fear Watershed

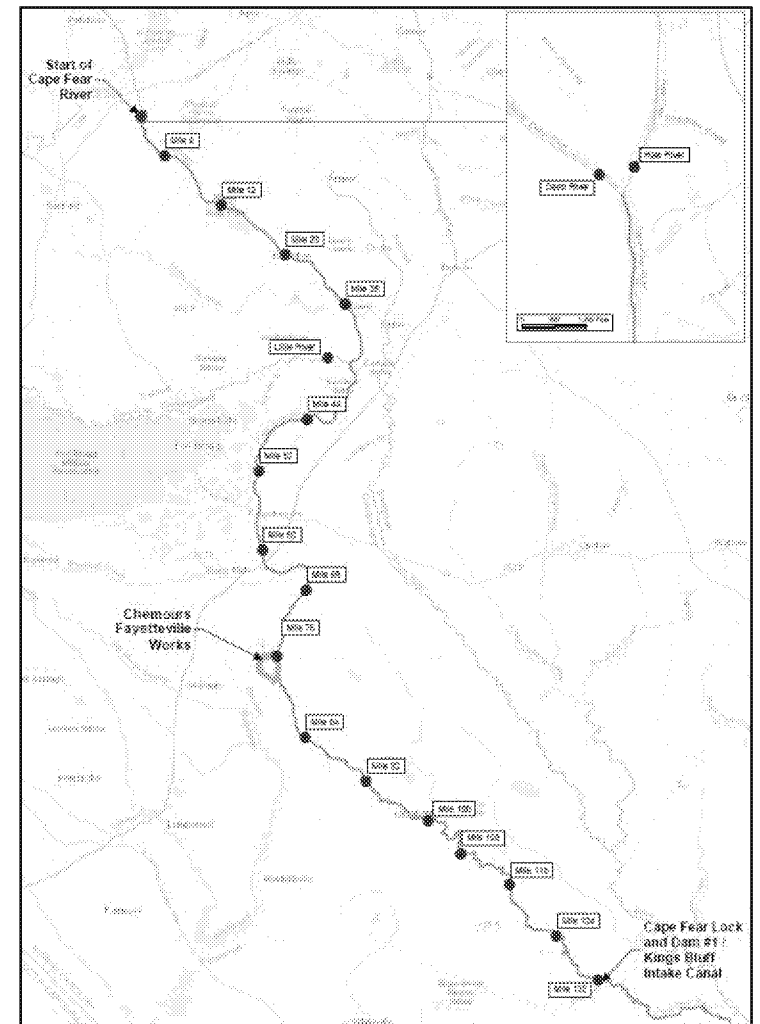


Sampling Program Locations

Local Programs (Sept. 2017, May 2018)

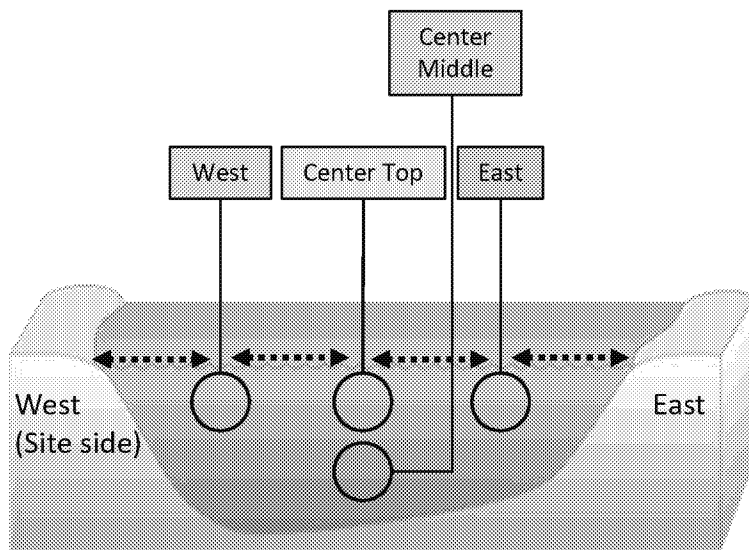


Regional River Program (June 2018)



River Sampling Locations

Local Programs (Sept. 2017, May 2018)



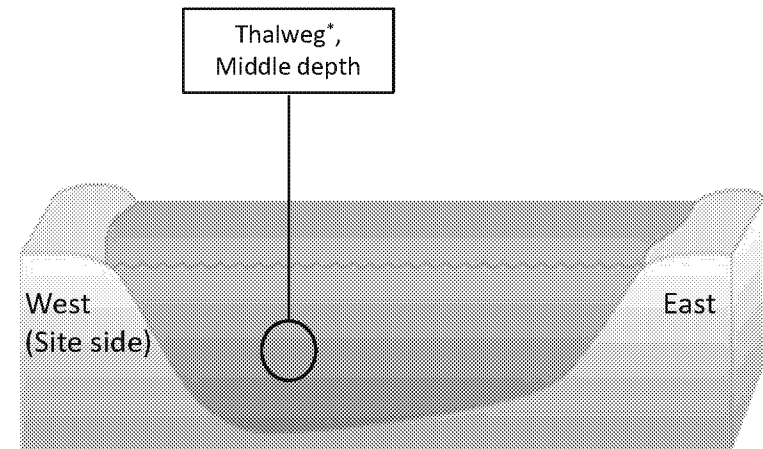
←.....→ 25 % of River width

Sampling Location Selection Rationale:

- Assess how concentrations differ across cross-section, particularly close to Site



Regional River Program (June 2018)

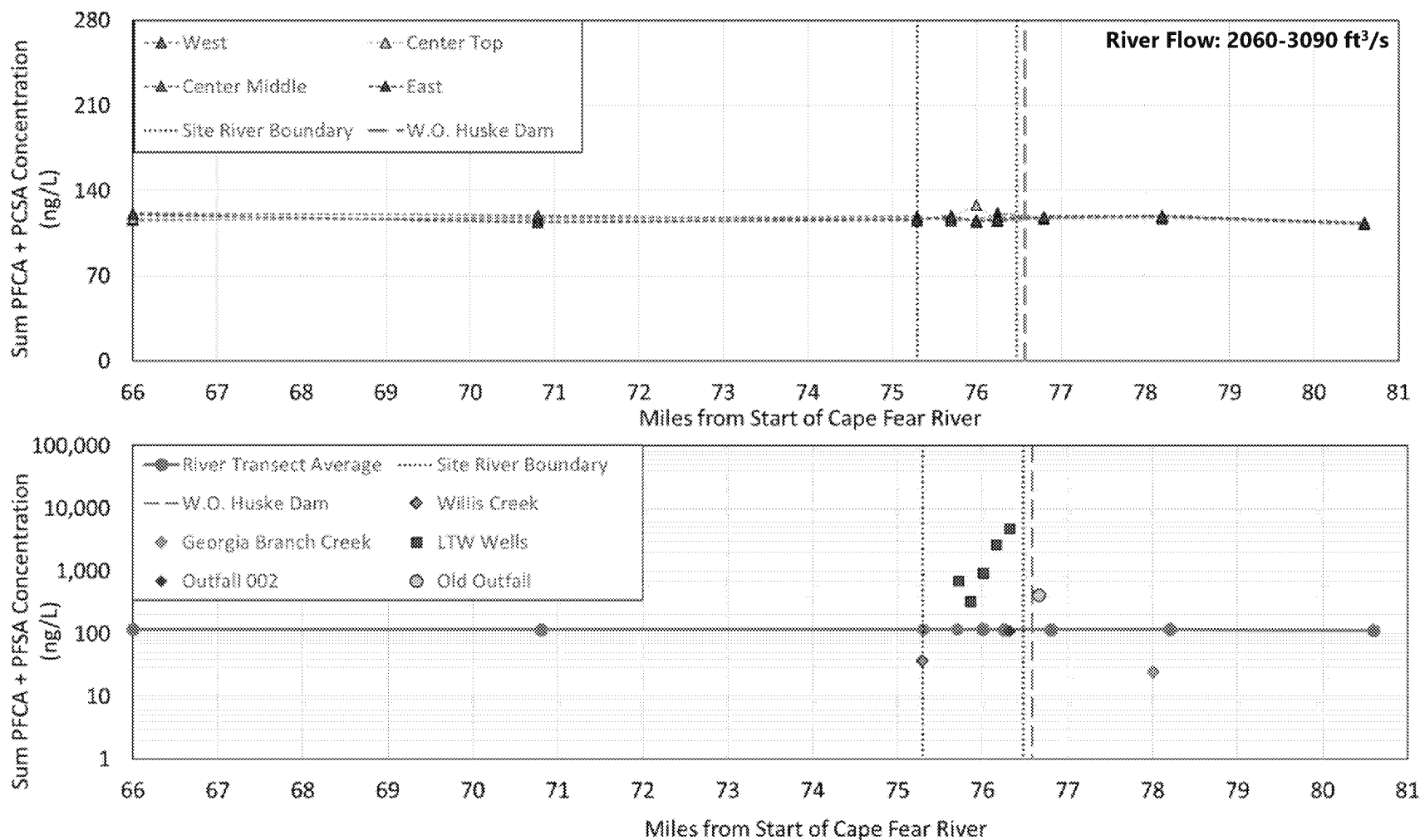


*Thalweg: Deepest part of the channel cross section

Sampling Location Selection Rationale:

- Collect well mixed representative samples along length of the River.
- Majority of flow typically occurs at the thalweg. Typically most mixed part of River and representative of average concentrations.

PFCAs + PFSA's May 2018



ng/L – nanograms per liter, equivalent to ppt (part per trillion)

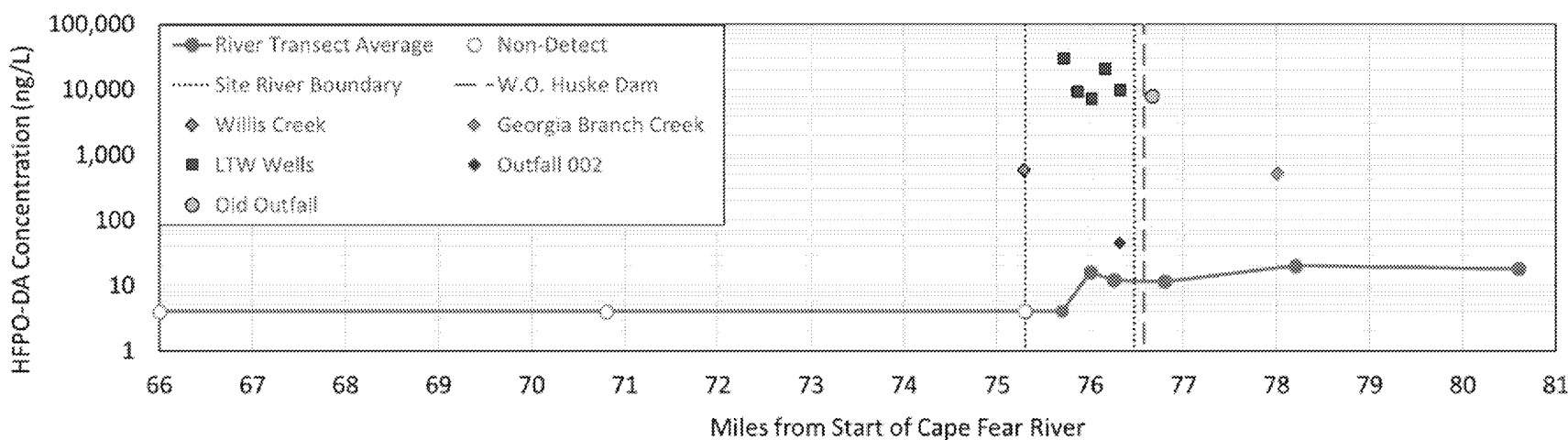
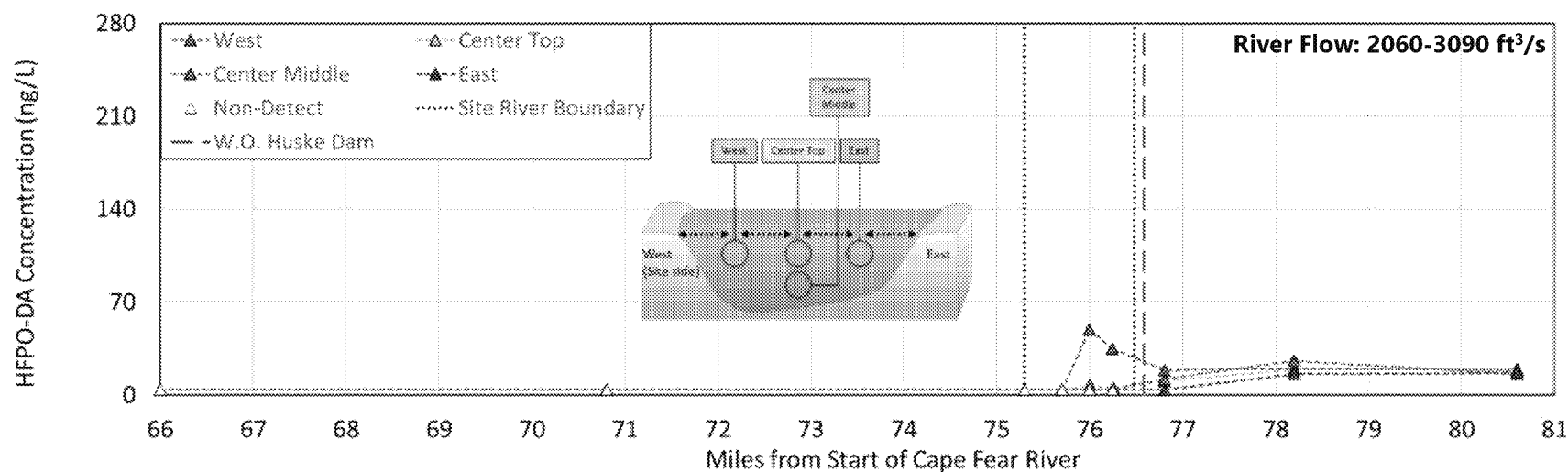
LTW – Long Term Well

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HFPO-DA May 2018



ng/L – nanograms per liter, equivalent to ppt (part per trillion)

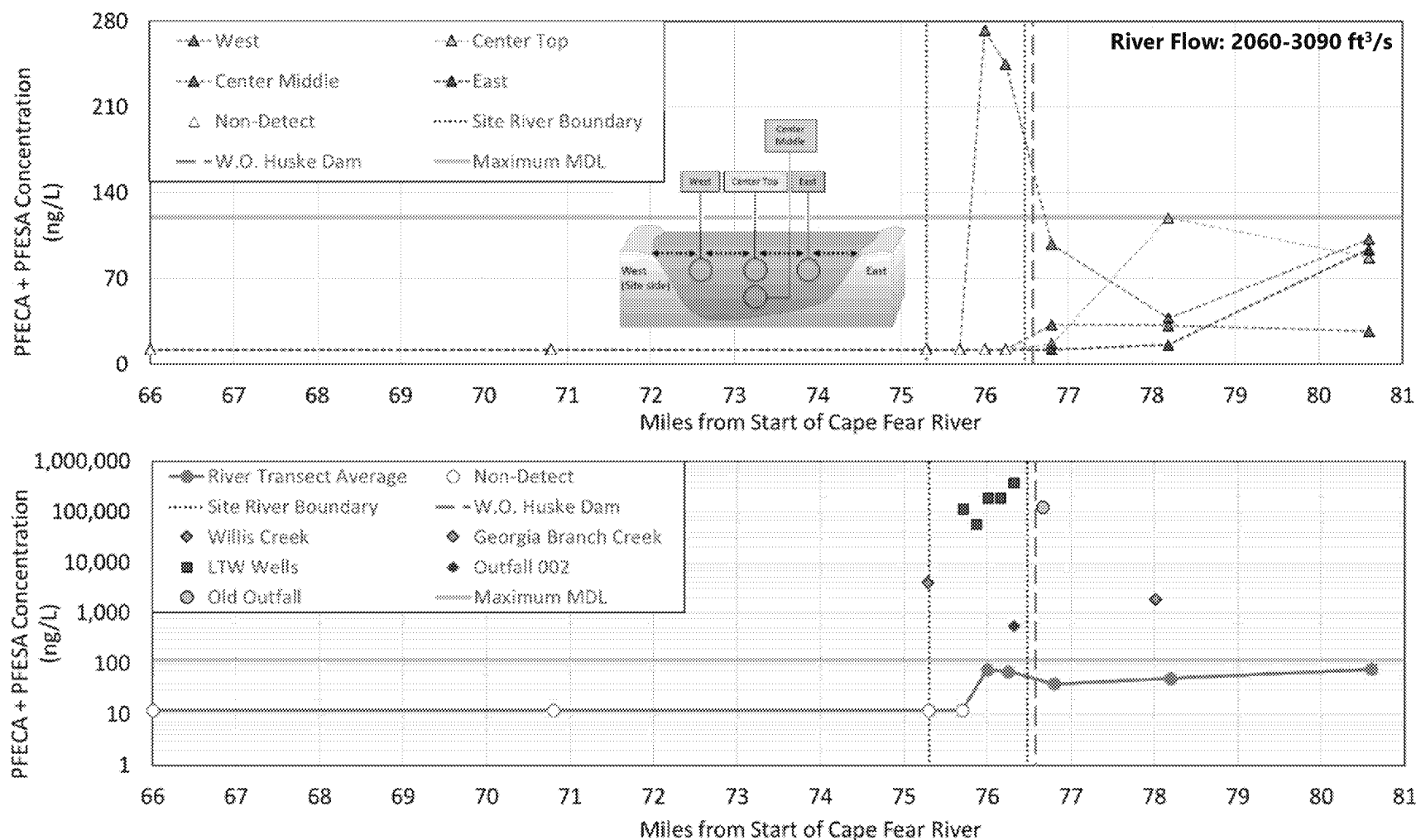
LTW – Long Term Well

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31-Jan-2019

FW003077

ED_005565_00003495-00038

PFECAs + PFESAs May 2018



Chemours™

ng/L – nanograms per liter, equivalent to ppt (part per trillion)
LTW – Long Term Well

Note 1: Maximum MDL, 120 ng/L, is the statistical MDL for PFESA BP 1, the highest Table 3 MDL.

Note 2: Non-detect data are plotted at 12 ng/L, the lowest detected PFMOAA concentration. 31-Jan-2019

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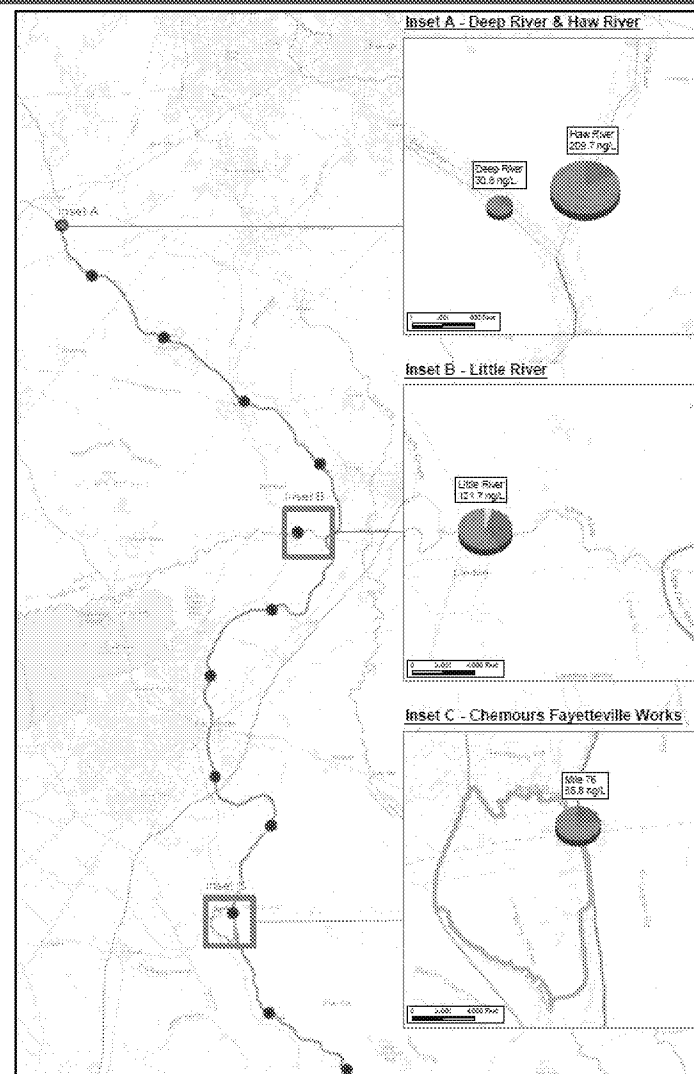
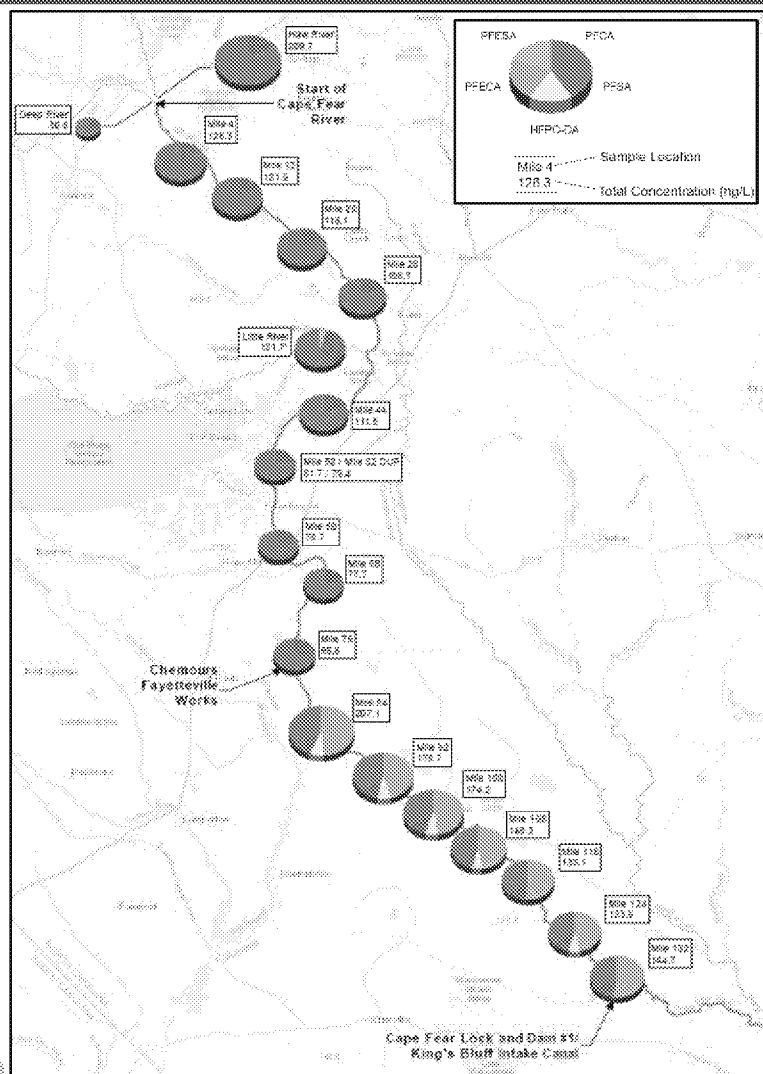
Primary Local Sampling Program Observations

- PFCAs and PFSAAs are not related to Site
- HFPO-DA, PFECAs and PFESAs
 - Present only after Site; are related to the Site
- HFPO-DA remains below health goal of 140 ng/L
- Actions taken and underway by Chemours have reduced and will continue to reduce Cape Fear River HFPO-DA, PFECA and PFESA concentrations



Regional River Sampling Results (June 5th to 8th 2018)

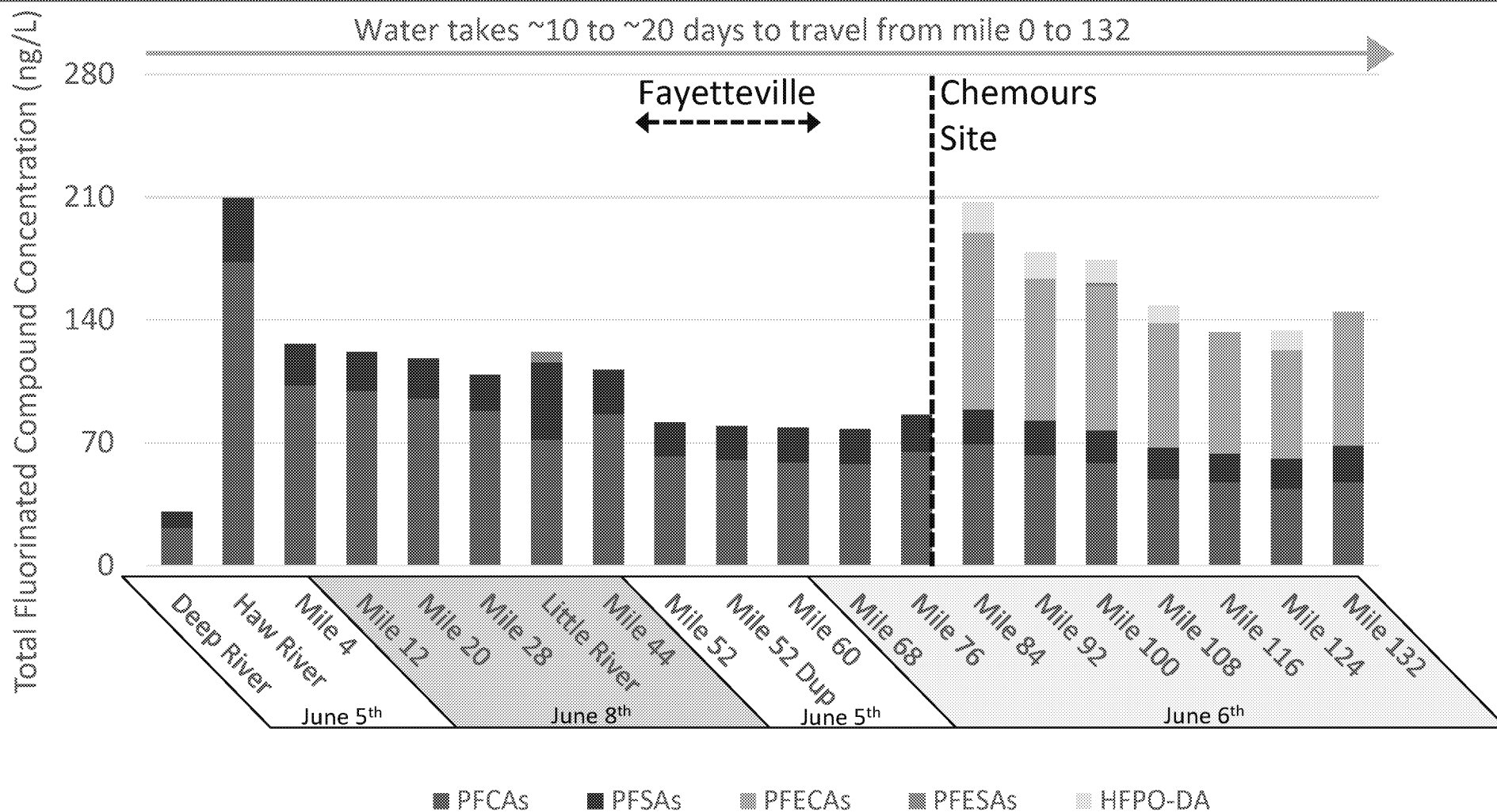
2 of 2



ng/L – nanograms per liter, equivalent to ppt (part per trillion)

Regional River Sampling Results (June 5th to 8th 2018)

1 of 2



ng/L – nanograms per liter, equivalent to ppt (part per trillion) * Dup – Duplicate sample



Regional River Observations 2 of 2

Data Observations

- PFCAs and PFSAAs present along entire River
not attributed to Site
- HFPO-DA and PFECAs only present after Site
attributed to Site
- Haw River highest PFCAs; Little River highest PFSAs
- HFPO-DA remains below health goal of 140 ng/L
- Actions taken and underway by Chemours have reduced and will continue to reduce Cape Fear River HFPO-DA, PFECA and PFESA concentrations.



Recent Table 3 Data in Cape Fear River

Sampler	Chemours	Chemours	Chemours	CFPUA	Chemours
Location	CFR-09	RM-84	Kings Bluff Canal	Sweeney Raw	Kings Bluff Canal
Miles Down River from Site	5	8	55	55	55
Date	10-May-2018	6-Jun-2018	6-Jun-2018	8-Oct-2018	1-Nov-2018
HFPO-DA; GenX	20	17	10 U	11	15
PFMOAA	67	80	57	7.69	26
PFO2HxA	20	21	19	5.23	13
PFO3OA	88 U	88 U	88 U	ND	3.2
PFO4DA	97 U	97 U	97 U	1.55	2 U
PFO5DA or TAF	110 U	110 U	110 U	--	2 U
PFECA G	96 U	96 U	96 U	ND	2 U
PMPA (PFMOPrA)	84 U	84 U	84 U	4.15	16
PEPA (PFMOBA)	100 U	100 U	100 U	ND	2.3
PFESA BP 1	120 U	120 U	120 U	ND	2 U
PFESA BP 2	95 U	95 U	95 U	ND	2 U
Total	107	118	76	30	76
River discharge (cf/s)	2,138	2,085	2,490	11,100	8,770

- Reported concentrations are estimates made below the method reporting and detection limit.
- Table 3 analytical has since become more sensitive with lower reporting limits.



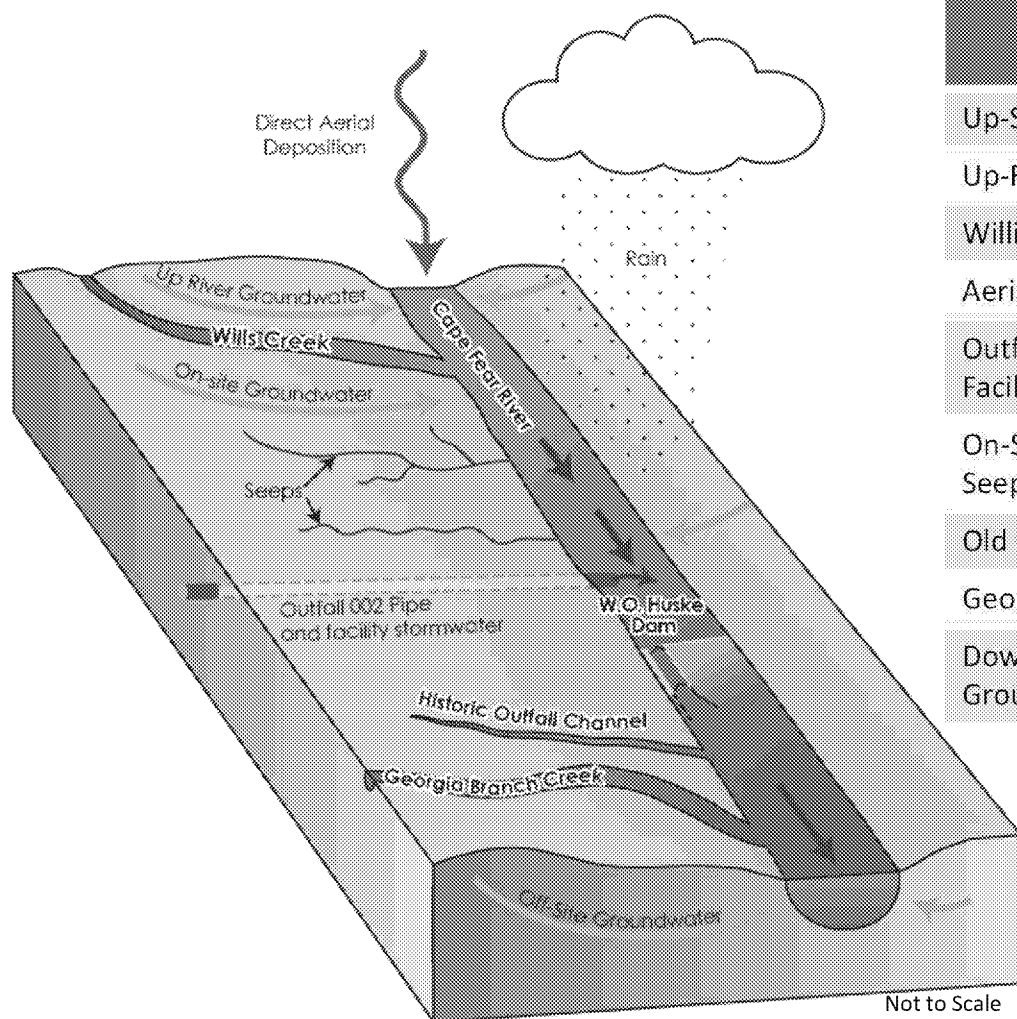
Recent Table 3 Data in Cape Fear River Observations

- HFPO-DA and Table 3 compounds are detected at Kings Bluff Intake
- Oct. and Nov. 2018 Chemours and CFPUA analyses detected between four to five Table 3 compounds at Kings Bluff Intake
- Table 3 compound detections in Oct/Nov samples using enhanced analytical methods are lower than the estimated May and June analytical results



River Mass Flux

Mass Flux Compartment Model Inputs



Potential Pathway	Concentration Data	Flow Data
Up-Stream River	Measured	Measured
Up-River Groundwater	Residential Well Data	Calculated
Willis Creek	Measured	Measured
Aerial Deposition on River	Modeled / Calculated	
Outfall 002 including Facility Stormwater	Measured	Measured
On-Site Groundwater & Seeps	Measured	Calculated
Old Outfall 002	Measured	Measured
Georgia Branch Creek	Measured	Measured
Down-River (Off-Site) Groundwater	Residential Well Data	Calculated



Mass Flux Compartment Model

26-27 September 2017 River Data

Potential Pathway	Concentration (ng/L; ppt)	Flow Data (L/s)	Mass Flux (ng/s)	Contribution to River Concentration (ng/L)
Up-Stream River	0	25,500	0	0
Off-Site Groundwater (Up & Down River)	147 – 179	110 – 180*	16,000 - 32,250	0.5 - 1.25
Willis Creek**	310 – 450	170 – 250	52,700 - 112,500	2.0 - 4.5
Aerial Deposition on River	--	--	6,000*	0.25
Outfall 002 and facility stormwater	35	900	31,500	1.25
On-Site Groundwater (and seeps)	25,000 – 50,000	12 – 24*	300,000 – 1,200,000 [‡]	12 – 47
Surface Water Run-Off†	NA	NA	0	0
Old Outfall**	8,400	27	227,000	9
Georgia Branch Creek**	540 – 1,100	8 – 16	4,500 – 17,500	0.2 – 0.7
Total	--	--	665,000 – 1,625,000	26 – 64
Measured Down River 5 Miles	39.25	25,500	1,000,000	39.25

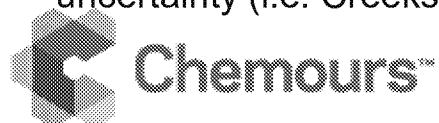
* Data are a combination of measured data, supporting calculations and best estimates selected using professional judgement.

** Historic Outfall flow and concentration data are solely from 18-January-2018; Willis Creek and Georgia Branch Creek flow data are from 18-January-2018.

† During 26-27 September 2017 Surface Water Run-Off not possible. No rain during/before event.

‡ Groundwater flux range estimated assuming discharge areas of 37,000 to 20,000 m², measured LTW Wells to Cape Fear River gradients of 0.064, measured concentration range of 50,000 to 25,000 ng/L, and a estimated hydraulic conductivity of 10⁻⁵ m/s, representative of silty sand.

- Largest contributors to river HFPO-DA load are: Old Outfall 002 and On-Site Groundwater / Seeps
- Groundwater has highest degree of uncertainty
- Compartments / pathways where flow and concentration can be measured rather than estimated have less uncertainty (i.e. Creeks and Outfall 002 have less uncertainty)



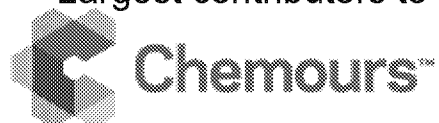
Mass Flux Compartment Model

9-10 May 2018 River Data

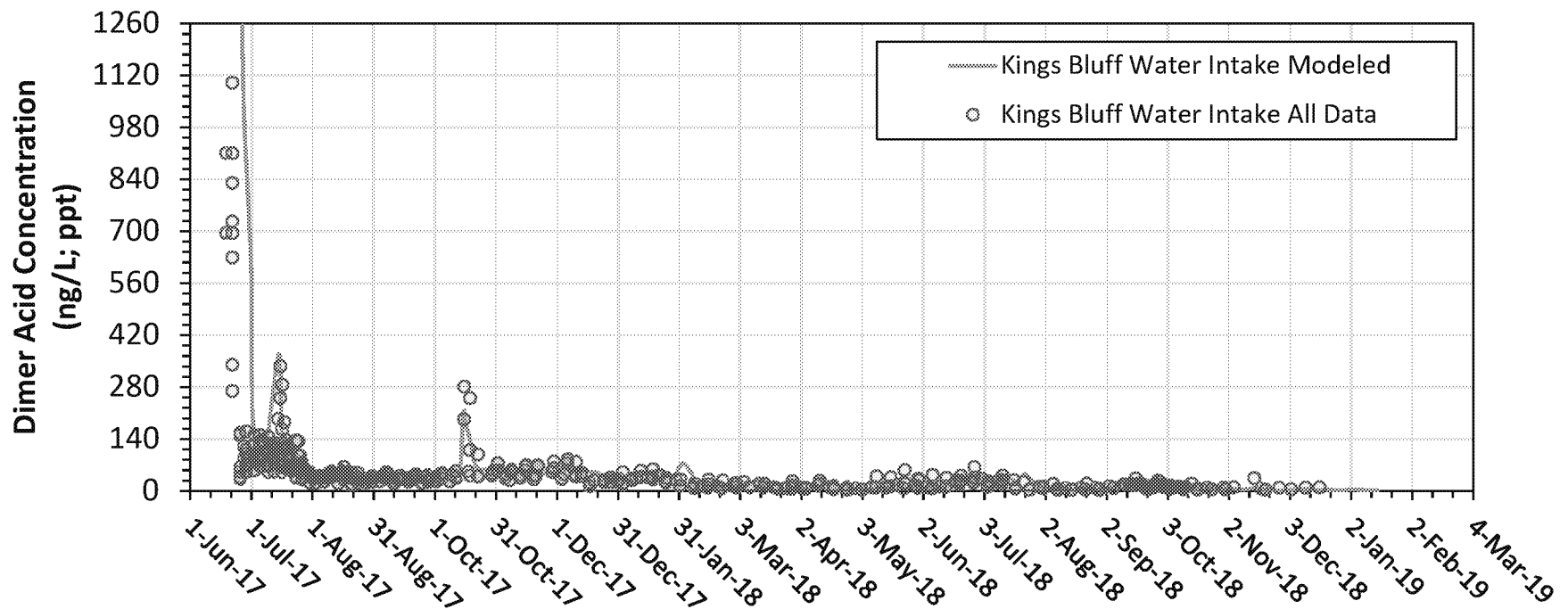
Potential Pathway	Concentration (ng/L)	Flow (L/s)	Mass Flux (ng/s)	Estimated Contribution to River Concentration (ng/L)
Up-Stream River	0	59,000 - 82,500	0	0
Willis Creek	560 - 590	115	64,500 - 68,000	0.8 - 1.2
Aerial Deposition on River ¹	--	--	3,900	0.048 - 0.067
Outfall 002 and facility stormwater	45	910 - 1,000	41,000 - 45,000	0.5 - 0.76
On-Site Groundwater (and seeps)	7,400 - 30,000	12 - 24	90,000 - 720,000	1.1 - 12.2
Surface Water Run-Off (dry)	NA	NA	0	0
Old Outfall	8,000	32	256,000	3.1 - 4.3
Off-Site Groundwater (Up & Down River) ⁵	147 - 179	110 - 180	16,000 - 32,000	0.2 - 0.55
Georgia Branch Creek	520	9	4,700	0.057 - 0.079
Total Estimated Mass Flux and Corresponding River Concentration	--	--	460,000 - 1,129,600	5.75 - 19.2
Measured⁶ Concentration and Flow Down River 5 Miles and Calculated Mass Flux	18	60,600	1,090,800	18

* Data are a combination of measured data, supporting calculations and best estimates selected using professional judgement.

- May 2018 Mass Flux Compartment model constructed using same basis as September model
- Creeks and Old Outfall 002 were sampled and gauged during the May 2018 river sampling event
- River flow volumes ranged from 2,080 to 2,920 cubic feet per second (i.e. 59,000 to 82,500 liters per second)
- Largest contributors to river HFPO-DA load are: Old Outfall 002 and On-Site Groundwater / Seeps



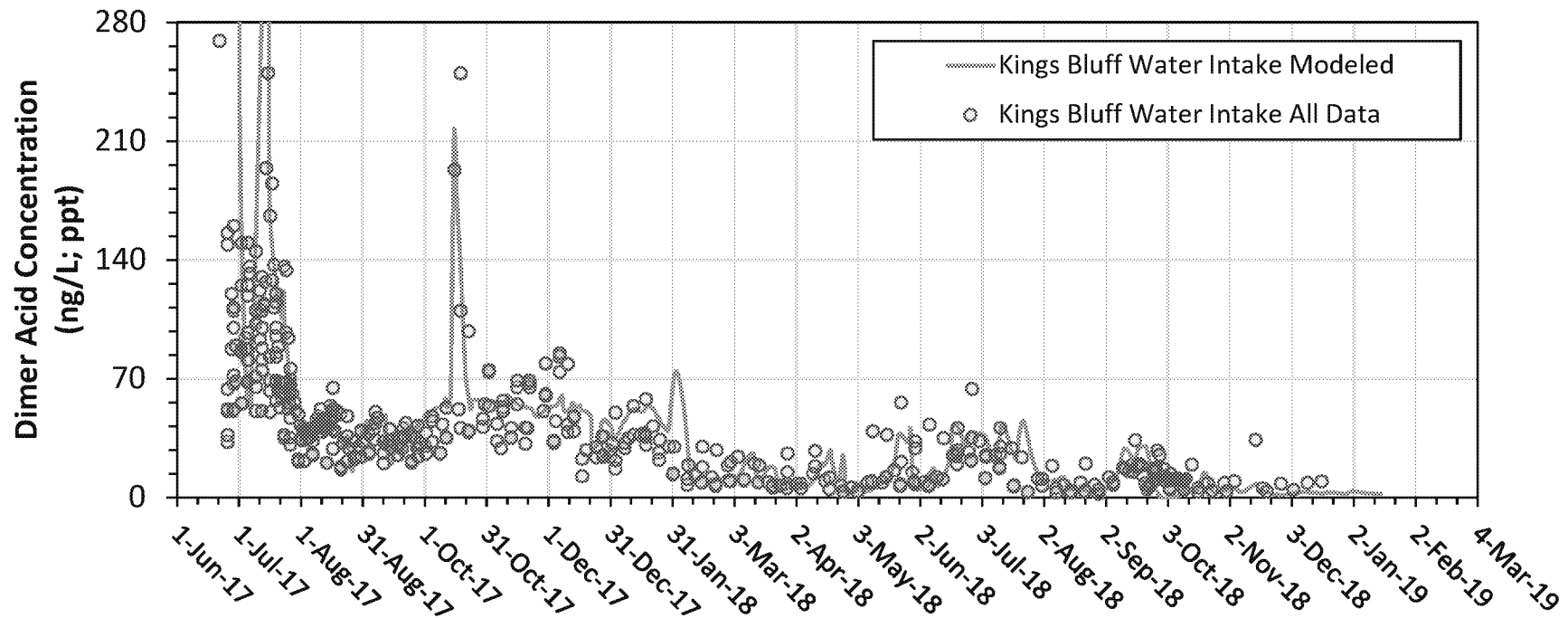
River Mass Flux Model Results



- Predicted concentrations vs. data from Kings Bluff Intake / CFPUA samples
 - Blue line → modeled river concentrations.
 - Circles → river HFPO-DA measurements posted online by NCDEQ, CFPUA, Brunswick County
- HFPO-DA in Cape Fear River remains below 140 ng/L after October 2017.



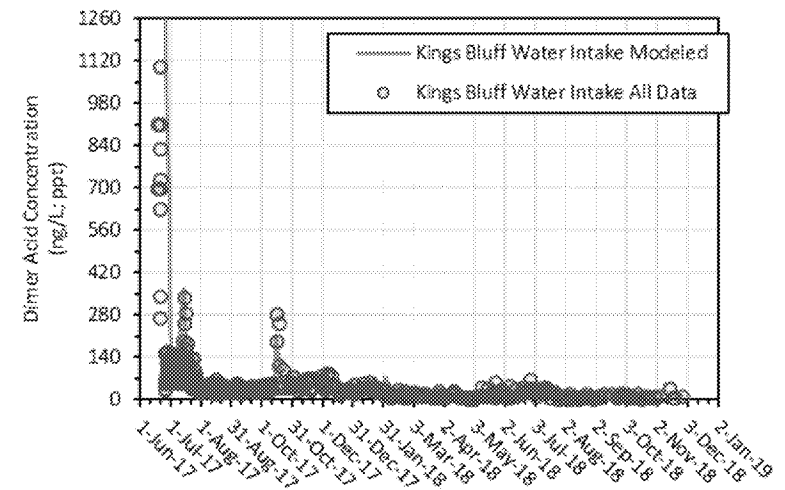
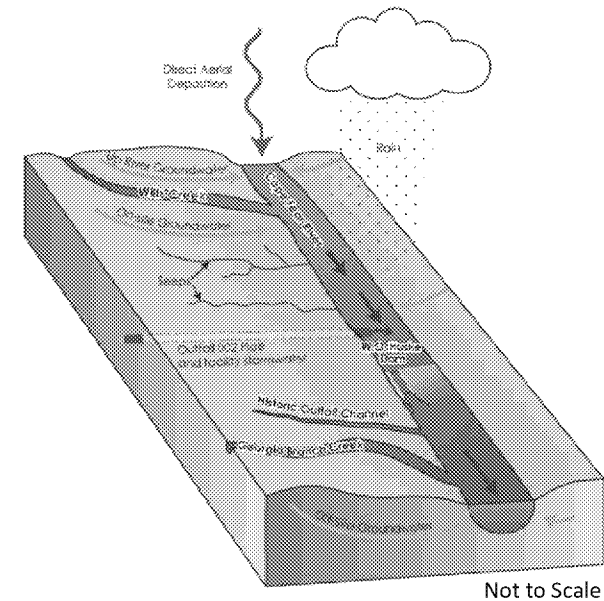
River Mass Flux Model Results, Zoomed in y-axis



- Predicted concentrations vs. data from Kings Bluff Intake / CFPUA samples
 - Blue line → modeled river concentrations.
 - Circles → river HFPO-DA measurements posted online by NCDEQ, CFPUA, Brunswick County
- HFPO-DA in Cape Fear River remains below 140 ng/L after October 2017.

Mass Flux Model Findings

- Cape Fear River HFPO-DA concentrations remain below 140-ng/L
- Expected river concentrations can be modelled.
- HFPO-DA River Concentrations Controlled By:
 - **Outfall 002.** Increases to Outfall 002 mass flux may increase river concentrations. Depends on river flow volumes.
 - **Groundwater / Seeps and Old Outfall 002**
These compartments account for most HFPO-DA to the river
 - **River Flow Volumes.** Storms add more water into river.



Mass Flux Compartment Model

Potential Pathway	Concentration (ng/L)	Flow (L/s)	Mass Flux (ng/s)	Estimated Contribution to River Concentration (ng/L)
Up-Stream River	0	37,000	0	0
Willis Creek	560 - 590	115	64,500 - 68,000	1.7 - 1.8
Aerial Deposition on River	--	--	3,900	0.11
Outfall 002	33	910 - 1,000	30,000 - 33,000	0.8 - 0.9
On-Site Groundwater & Seeps	7,400 - 30,000	12 - 24	90,000 - 720,000	2.4 - 19.5
Surface Water Run-Off to Outfall 002	NA	NA	0	0
Old Outfall 002	8,000	32	256,000	6.9
Off-Site Groundwater (Up & Down River)	147 – 179	110 – 180	16,000 - 32,000	0.4 - 0.9
Georgia Branch Creek	520	9	4,700	0.13
Total Estimated Mass Flux and Corresponding River Concentration	--	--	460,000 - 1,100,000	12 - 35
<u>Measured</u> Concentration and Flow Down River 5 Miles and Calculated Mass Flux	18	37,000	670,000	18

May 9-10 Data set



Presentation End